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THE AUGUST SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

AUGUST, 1932

THE TIME SCALE[1]

THE CONCEPT OF TIME

By Dr. PERCY W. BRIDGMAN

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THE concept of time which I shall talk about is not the profound and sometimes poetic concept of the philosopher, but the prosaic concept of the physicist. I hope it will not be presuming too much to assume that this is also the concept of the astronomer, for I suppose that most of us will agree that the astronomer is a sort of physicist—whether a super- or a sub-physicist I shall not attempt to discuss.

As you all know the physicist has discovered recently that he must demand as essential in all concepts which can be useful to him a certain fundamental quality which I have ventured to call "operational." That is, the meaning of any concept is to be sought in the operations, whether physical or mental, which are performed in making application of the concept. This point of view received its first and perhaps most important application by Einstein in his analysis of the concept of simultaneity, and has by now become fundamental in wave mechanics as expounded by Bohr, Heisenberg, and Dirac.

Applying the operational criterion to time, the meaning of the concept of time, as it is employed by physicists and astronomers, is to be sought in the operations by which the time at which events occur is determined. The methods which we adopt for assigning a time to events change when the character of the events changes, so that time may appear in various guises. The simplest events to deal with are those taking place here and now. The time which we assign to such events may be called, following the theory of relativity, the "local time." One aspect of such local time is of such irreducible simplicity that no way has yet been found which does not treat it as unanalyzable; this of course is not a reproach because unanalyzables must always terminate any logical analysis. The aspect to which I refer is that of simultaneity—we assume that we can tell intuitively when two events in my immediate vicinity occur simultaneously. The concept of the simultaneity of two events occurring at a distance from each other is much more complicated, and it was Einstein's analysis of this which was mainly responsible for the special theory of relativity. But the simultaneity concept is not enough even for local time; in addition we must have some method of measuring local time, that is, some method of assigning numbers as the time of local events. An instrument by which such numbers are assigned is called a

[1] A symposium at the Harvard Observatory on the occasion of the dedication of the Astrophotographic Building, March 23, 1932. The new building contains the large collection of photographic plates, the library of the observatory, and many offices.

clock, but if any one should ask me for directions for constructing a clock or for specifications by which he could determine whether an instrument which purported to be a clock was actually one or not, I could not give him a satisfactory answer. In fact, here at the very root of one of our most fundamental concepts is a surprising deficiency—no satisfactory definition has yet been given of a clock. The best that we can do is to point to actual mechanical systems which we choose to call clocks, and you are of course proudly conscious that the clocks *par excellence* are afforded by the bodies of astronomy.

Distant events, of which knowledge can be obtained only by light signals, must have time assigned to them by more complicated operations than those which suffice for the local system, and this means that in our thought the time of distant events must be distinguished from the time of local events; we may distinguish by calling the time of distant events "extended" time in contrast to the "local" time of near-by events. The astronomer is obviously dealing almost entirely with extended time. It is nevertheless true, I believe, that nearly all astronomers think of the extended time of distant events in terms of the connotations of the local time of their own personal experience. For example, it is quite usual for an astronomer to speak of the "age" of a light beam, and he sometimes seems to get a particular sort of kick from the realization that the light which he receives to-day from the most distant nebula may be of the order of 100 million years old. On reflection it is obvious enough that the "old" as applied to a light beam has entirely different connotations from the "old" which may describe a hat or even a fossil at the bottom of the Grand Canyon. We have in the first place the dictum of relativity that the beam of light itself does not grow old or that if you or I could accompany the light beam on its travels we also would not notice the passage of time, but would live through the entire 100 million years with no change in any of our bodily functions, and without the need of even a single meal. What we mean when we say that the light beam is one hundred million years old is that it left the nebula one hundred million years ago, and what we mean by this again requires the most careful analysis. To give this meaning we must assign a distance to the nebula, and obtain the time by dividing the distance by the velocity of light. But to get the distance is not at all straightforward, and involves all sorts of assumptions and approximate reasonings by analogy, which leave an enormous possibility for error in the final result. It is popularly supposed that astronomy is a science of fabulous accuracy, but the accuracy is all of a special kind, namely, accuracy of angular position, whereas most distances are not at all well known, for even the most accurate may be uncertain by something of the order of one part in 10,000. It is evident, therefore, that the connotations in saying that a beam of light left a nebula one hundred million years ago are so different from the connotations involved in the time back to remote events on this earth as to make it an almost different concept.

It is also not unheard of to allow oneself to wonder what may be happening on some distant star "now." To give meaning to this question there must be some way of answering it. Even in thought the only way for me to find what is happening "now" in the distant nebula is to send a wireless message to my confederate in the nebula, who will receive it after one hundred million years, and then must consult what may be his equivalent for the library of the British Museum, where he will almost certainly find only the sketchiest sort of record of what was happening one hundred million years ago. He will then wireless the message to me, who will re-

ceive the reply at the advanced age of two hundred million years, and the reply will probably be nothing more specific than the statement that during the 10,000 years centering around the day on which I made my original inquiry a certain kind of rock was being laid down. The connotation of the "now" in distant places is obviously so different from that of ordinary experience as to make this a different concept.

We have so far assumed that there is no difficulty with the concept of remotely distant time in the local frame of reference. By this I suppose we mean that some method exists by which we can satisfactorily assign dates to local events in the remote past. There is, however, a very important limitation on the meaning that can be assigned to remote time imposed by the Heisenberg uncertainty principle. Position and velocity can not both be measured with unlimited precision, but there is a mutual restriction. If I make any sort of a determination of the position of an object, I thereby introduce an uncertainty into its velocity. But if the position of the body in past time is to be found, I must know its velocity, so that any uncertainty in its present velocity involves an uncertainty in its past position. It is obvious, I think, that the further back in time we go, the greater becomes the uncertainty in position. If we go back far enough the position becomes so blurred as to make our original object indistinguishable from others, and the past becomes radically different from the present in that the identity concept disappears. In the same way, the future becomes more and more blurred the further ahead we try to predict, until all details are lost. It is not hard to calculate that after a lapse of something like 10^{100} years the identity of any two originally distinct stars would be entirely confused, so that one must not try to peer as far as this into the future. It is not uncommon, however, to speculate about intervals of time in connection with a possible Poincaré-Zermelo cycle of the whole universe in comparison with which 10^{100} years is the mere drawing of a breath.

Not only does the astronomer deal with long intervals of time in the past in thinking about the time of dispatch of light signals which are now arriving at the earth, but he deals with enormously greater intervals of both past and future time in tracing backward or forward the course of stellar evolution in his search for the origin or ultimate destiny of the stellar universe as we know it. It is here, and in a degree characteristically peculiar to astronomy, that the greatest assumptions have to be made, and it seems to me that there is also the greatest need for perpetual vigilance and the most vivid consciousness of exactly what we are doing. Any reconstruction of the past or extrapolation into the future from observations of present configurations can be made only by assuming certain laws governing the motions. Thus we assume the conservation of linear momentum or the conservation of angular momentum, or the conservation of energy, or, if we seek for special refinement, we assume the generalized equations of relativity. But these laws themselves are generalizations from past experience, and are affected with all the uncertainty pertaining to any result of experience. To the untutored critic it must appear a trifle rash to venture to peer 10^{16} years back into the past or even greater distances into the future on the basis of laws verified by not more than 300 years' observation. The only justification for such hair-raising extrapolations is to be found in the tacit assumption of some system of metaphysics; we are convinced that nature obeys mathematically exact rules, and that we have found some of them. The reason we are convinced that we have found them is that our metaphysics persuades us that nature has a taste for the

law of the inverse square or for some other rule which our gray matter finds it comparatively easy to formulate. The metaphysical conviction that we have penetrated the arcana of nature is particularly strong in the adherents of generalized relativity, who are so convinced of the inevitableness of their philosophy that they are persuaded that even the stars in their courses must recognize the cogency of the argument. There has been no more surprising spectacle afforded by science for many a year than that of the two leading British astronomers lying down together like the lion and the lamb, giving up their most cherished and potent arguments of a few moments before, and joyfully accepting a reduction of a million fold in the time scale of the universe on the basis of a metaphysics and three not too certain checks with experiment. Surely there are plenty of unexplained phenomena to disturb so easy a complacency—the cosmic rays, which were discovered only yesterday, are becoming less well understood with every fresh investigation, the *raison d'être* of the heavy stars is at least obscure, the whole theory of stellar structure seems alarmingly chaotic to an ignorant physicist, and to-day on the front page of the papers is the "neutron," which certainly carries the potentiality of a certain amount of reconstruction.

Destructive criticism is always easy, and I am afraid that I am even more blameworthy than the ordinary destructive critic. I have nothing else to suggest, and I am sure that I would have been overcome with pride if I had had the ability to construct any one of the important modern theories. But I hope that I should not have taken what I might have done too seriously; that I would have recognized that I was merely carrying through to their logical conclusion certain consequences of formulations which I had found it convenient to make in getting into touch with the external world, and that I would have recognized, therefore, that I was to a certain extent only playing an absorbing mental game with myself. I hope that I should have been on the everlasting lookout to recognize that all my laws were probably inexact, and that I should have certainly been trying to make new experiments and better observations to get a little closer to things as they are, as I am sure all the astronomers here are doing already.

THE ASTRONOMICAL MEASUREMENT OF INTERVALS OF TIME

By Dr. ROBERT H. BAKER

PROFESSOR OF ASTRONOMY AND DIRECTOR OF THE OBSERVATORY, UNIVERSITY OF ILLINOIS

My share in these proceedings is simply to recall to those who work in other fields some features of the astronomical problem of time keeping. It is convenient for most of our purposes to suppose, with Newton, that time flows on uniformly forever, unaffected by anything else. To symbolize this concept we may imagine a body having perpetual and uniform motion in a straight line, and may keep time by measuring its progress with an appropriate yardstick. Perfectly uniform periodic motion is still more satisfactory, since this sort of motion supplies its own yardstick, the period of the oscillation.

Our problem is to contrive such an oscillator, or to find one in nature, or per-

haps several having widely different periods. It is fortunate for this purpose that so many celestial phenomena are periodic.

Axial rotation is frequent among the celestial bodies. The planets and their satellites, the stars, clusters of stars, and even the remote nebulae are known to be rotating. Mutual revolutions of associated bodies are frequent occurrences, as we see with the telescope in the case of visual double stars, or by oscillations of lines in stellar spectra, or by fluctuations in brightness as revolving stars mutually eclipse.

Eclipses of the sun and moon recur in definite cycles. Specifications of planetary orbits, such as the eccentricity of the earth's orbit or its inclination to the ecliptic, fluctuate. These are some of the periodic phenomena from which units of time of various lengths might be chosen. Often their periods are well known. Unfortunately, however, their periods are not, in general, constant.

Thus far, man has selected from the natural time units those most immediately connected with his ordinary affairs, namely, the periods of the earth's rotation, the moon's revolution, and the earth's revolution. The alternation of day and night, the cycle of the moon's phases, and the round of the seasons have drawn special attention to these periods.

The smallest of the natural time units, the day, the period of the earth's rotation, is readily established by observing the apparent rotation of the celestial scenery in the opposite direction to our movement. As the tape at which the celestial body under observation is supposed to finish its daily circuit, we select ordinarily the celestial meridian, running north and south across the sky. And to aid in timing its start and finish as accurately as possible, the transit instrument is employed; it is a small telescope mounted on a single axis in such a way that it points always along this circle of the sky.

The kind of day that is observed depends on the object chosen. If one of the stars is selected, any one which is fixed in its place relative to the others for this short duration, the day is the mechanical period of the rotation. If we select the vernal equinox, which is itself moving westward very slowly among the stars, this day, the sidereal day, is eight thousandths of a second shorter. If we select the sun, which moves eastward against the background of the stars, this day, the apparent solar day, is longer by nearly four minutes than the sidereal day.

It is not a serious matter if the length of our unit varies, so long as we know how it varies and can allow for it. The apparent solar day is conspicuously variable. But the variations are compensated for during the course of the year. The average apparent day, which is the mean solar day, is our smallest and chief time unit.

The earth's rotation is the master clock by which all terrestrial and celestial events are timed. Or what amounts to the same thing, the apparent daily rotation of the heavens is the master clock. If an hour hand is needed, we may supply it by drawing a line from the mean sun to the celestial pole in the northern sky.

It is a simple matter to read the time from this master clock. But we are disturbed by the thought that the clock may not after all be reliable. Is the earth's rotation a perfect example of perpetual, uniform motion, or is it not?

Several possibilities occur to us—several factors which may well cause our master clock to run off one way or the other. The fall of meteors upon the earth should retard the works, and those falling into the sun should produce a slipping of the hour hand, both factors conspiring to lengthen the day. Unless the supply of meteoric material is evenly distributed through space, which seems

unlikely, its contribution to the delinquency of our clock should be variable.

The Mississippi River, by transporting great quantities of material southward to regions farther removed from the center of the earth, is putting a brake on the earth's rotation. Man produces a like effect when he takes material from below the earth's surface and places it above the surface. One could calculate, I suppose, the increase in the length of the day since the erection of the Empire State Building.

The tides act as a friction brake to retard the earth's rotation. Under their influence the length of the day appears to be increasing at the rate of a thousandth of a second a century.

Suppose that one should start out with a definite impression that his watch is perfectly reliable. Presently, however, he notices that every one else is proceeding on a different schedule. He misses a train; he is late for an appointment; the town clock is fast. Eventually, he questions the reliability of his watch. In the same way, we entertain doubts as to the uniform running of our master clock, inasmuch as independent periodic phenomena, such as the revolutions of the moon and planets, depart systematically from regular schedules.

Superposed on the tidal retardation there are abrupt changes in the length of the day, as Professor Brown has clearly demonstrated, sometimes in one direction, sometimes in the other. Evidently the period of the earth's rotation is not so nearly constant as it was formerly supposed to be.

In the meantime, great improvements have been made in artificial clocks. The Shortt clock has aroused special interest because of its remarkably uniform rate. The question is raised whether the artificial timepiece may not replace the natural one as the master clock, whether it may not be used as the standard in the study of irregularities in the earth's rotation.

For the next unit, the month, the period of the moon's revolution, we must make a selection also. The mechanical period, from a star to the same star again, is the sidereal month of 27⅓ days. The month of the phases, from full moon to full moon again, is more than two days longer, more nearly in agreement with the calendar month. For the year, it is convenient for some purposes to employ the sidereal period, the interval between successive conjunctions of the sun with the same star; for other purposes we take the year of the seasons, from the vernal equinox to the equinox again, a year which is 20 minutes shorter.

But these units become inconveniently small when we turn to problems of the earth's development—the problem of the age of the earth, which Professor Holmes' researches have illuminated, and the problem of its beginning, where Chamberlin and Moulton appear for the moment to hold the field. We could use a larger unit, and we look hopefully to the earth to supply it.

Present evidence appears to show that remote objects, such as the globular clusters and the great spiral in Andromeda, are passing by in the direction of the Southern Cross. It is as though we were moving in the opposite direction, towards Cepheus in the northern sky, at the exhilarating speed of three quarters of a million miles an hour. Since this direction is at right angles to that of the great star cloud in Sagittarius, where Dr. Shapley has placed the center of the system of the Milky Way, it is supposed by many that this rapid motion of the earth is its share in the rotation of the galactic system. The period of this rotation, which is millions of years at our distance from the center, may some day be the larger yardstick for measuring the durations of cosmic processes.

THE AGE OF MAN

By Professor EARNEST A. HOOTON
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MAN is a comparatively new animal, a zoological upstart. In the parade of terrestrial life he brings up the rear. It is not strange, therefore, that anthropology, the study of man, should be the unkempt urchin of the sciences, tolerated among his elders in hope of latent promise, rather than by virtue of achievement. In this program, the consideration of man fittingly might come last, were it not for the anticlimactic effect of a descent from the spiritual remoteness of celestial bodies to the corporeal proximity of the human animal and his odoriferous primate relations.

A distinguished geologist, in one of his popular and lucid intervals, has summarized the earth's history on the face of a clock, twelve hours representing three thousand million years, by a radioactive scale of time.[2] He allots to man the last 21⅔ seconds of this twelve-hour period. It is evident, therefore, that already I have enormously exceeded my due portion of this afternoon's program. Because anthropology is a shameless juvenile, pilfering from all the trees of knowledge, I have not hesitated to appropriate Dr. Chester A. Reeds' radioactive clock for anthropometric purposes. I propose to measure the time of man firstly by the duration of his culture, and secondly by the requirements of his physical evolution.

To measure man's antiquity by the age of his culture is to employ a very crude "rule of thumb." Man's culture is quite literally a "rule of thumb," since it is to the use of that mobile and opposable member that he owes most of the paraphernalia of his material civilization.

[2] Chester A. Reeds, "The Earth, Our Everchanging Planet," pp. 1–2, The University Series, The University Society, New York, 1931.

Let us place the most important cultural achievements of man in some sort of rough chronological order. The smelting of iron ores probably began in southeastern Asia Minor not much later than 1500 B. C., roughly 3,400 years ago. Bronze was cast in the same general area at least as early as the beginning of the third millennium before Christ, more than than 4,900 years ago. Copper was reduced from its ores, hammered and cast into tools, weapons and ornaments for perhaps a thousand years before its alloy, bronze, came into use. Thus six thousand years from to-day take us back to the Stone Age, even in those areas where human culture progressed with the greatest speed.

For perhaps four millennia before the age of metals, human society in the most favored regions was already well organized upon an artificial basis of existence. Some plants were cultivated for food, and animals had been tamed and bred for the use of man. Sedentary folk were living in village communities, in huts of wattle and daub, timber, mud-brick, or possibly rough stone. The humble earthen pot already was moulded and baked by the housewife. The husband and father laboriously chipped and polished his hard stone axes, hewed timber, tended herds and flocks, while his wife stayed at home, minded the baby, and doubtless hoed the garden. The Neolithic period in Mesopotamia may have begun as early as 8000 B. C. Ten thousand years take us back to the savagery of the Old Stone Age, even, probably, in the regions where civilization was most precocious.

Just about this time we overtake the glaciers in their last retreat. According to Professor Hugo Obermaier, the vari-

ous phases of the epiglacial fluctuations occupied a period of 16,000 or 17,000 years. In the later millennia of this interval, European men were gradually emerging from cave life; Azilians in the Pyrenees were painting pebbles with symbolic signs; their cousins in South Germany were burying the heads of their dead like eggs in nests; the fine stone chipping of earlier ages had given way to a pygmy flint industry. Most of this epiglacial period, going back perhaps as far as 25000 B. C., was devoted in Europe to the development of a highly diversified industry in small stone implements and bone tools, and to the rise and decline of a realistic art, including representations of men and animals—engraving on stone and bone, and polychrome mural decorations in the caverns of southwestern Europe. The producers of this Magdalenian culture were physically modern types of men, making a living by fishing and hunting.

The Magdalenians were preceded immediately by the Solutrians, fabricators of beautifully chipped laurel leaf-shaped blades, and next by the Aurignacians, of the same fundamental European long-headed type, devoid of archaic simian attributes, skilled workers in flint and stone, gifted sculptors in the round, with a decided preference for fat ladies as artists' models. Here archeologists reach such a state of quivering timorousness that they can no longer articulate dates. The Later Stone Age or Upper Paleolithic period is thought to have begun in Europe not earlier than 27,000 or 30,000 years ago. Some parsimonious chronologists would pare the estimate to 11,000 years.

During the maximum extensions of the Würmian glaciation and probably throughout the most of the last interglacial phase a beetling-browed, prognathous, shuffling race of Neanderthal man lived in Western and Central Europe. In spite of their apelike features, they made several varieties of flaked flint implements with finely retouched edges; they buried their dead with some ceremony, and they contested successfully with the cave bear the tenancy of caverns with southern exposures. Their sway in Europe is probably to be reckoned in some hundreds of millennia. Yet they were no pioneers. Before them in Western Europe were the Acheuleans, who made symmetrical almond-shaped fist axes, which may be found by the thousands in the glacial gravels of the Somme and other rivers of Western Europe. The men who made the crude precursors of the Acheulean fist axes—pear-shaped implements with coarsely flaked sinuous edges—were the Chelleans. We know none of their skeletons, but they dropped some of their earlier and cruder tools in the Cromer Forest beds, which stand at the base of the Pleistocene. It is probable that the Old Stone Age with its easily recognizable implements made from flint nodules began as early as the inception of the glacial period.

Peering back into the shadowy Pliocene we may discern, sixteen feet down in the Red Crag, the habitation level of the Foxhall men, who used fire and chipped from flint their borers, scrapers, and knives. Anthropology owes this discovery to Mr. J. Reid Moir, of Ipswich, England. Below the Red Crag and in the drift which caps the chalk plateaus of Kent, are found the amorphous, chipped, rolled, and patinated flints, which are called Eoliths—"stones of the dawn." Many of these are undoubtedly of natural origin, but some of them were assuredly utilized by early men who had not yet succeeded in fashioning their tools into recognizable shapes.

Under these considerations I do not think that we can date the beginnings of human culture—the first construction and utilization of tools and implements—much later than the second half of the Pliocene period.

Now if we revert to Dr. Chester

Reeds' radioactive chart of geologic time, we find that he assigns one million years to the Pleistocene period and six million years to the Pliocene. The anthropologist is wholly incompetent to judge of the validity of such scales, but the present writer prefers to be a radio-activarian rather than a sedimentalist. Then, if we plagiarize Dr. Reeds' radioactive clock, we find that the twelve-hour dial of man's culture represents no less than four million years. Each second represents 92.59 years. Accordingly, if man's culture was born at mid-Pliocene noon, he began to make Chellean fist axes at 9 P. M.; at 11.54 and 36 seconds he began to draw pictures of animals and to sculp his lady friends; at 11.58 and 12 seconds he was beginning to try to tame animals and plants, to build huts and to live in communities and to polish stone tools; at a little less than 37 seconds before 12 o'clock midnight he discovered the use of iron. Of course this cultural-archeological clock is hardly accurate enough to justify the splitting of seconds.

A rather larger measure of the age of man employs the stages of human evolution, suggested by the study of recent and fossil types of man. This is a sort of foot-rule, rather than a rule of thumb, for the acquisition of a stable supporting foot seems probably to mark, better than other anatomical features, the transition from the anthropoid to the humanoid type.

The outstanding and most distinctive bodily characters of man are the stabilized supporting foot, the enlarged brain, and reduced jaws with associated chin and nasal prominences. We have to look far back beyond the stretch of 25,000 years which has elapsed since the last glacial maximum, for the genesis of any of these features. As a matter of fact, I am unable to point to any item of man's anatomy which shows definite progressive evolutionary changes since the modern types of Aurignacian men succeeded the apelike Neanderthalers in the caves of Western Europe. Great toes may have become a little greater; little toes may have become somewhat more diminutive and degenerate, palates more contracted, and teeth more liable to rot, but none of these changes are certainly consistent or cumulative, nor do they obtain in all the existing races of mankind. The wholly modern types of Aurignacian man give way to the apish Neanderthalers at the maximum of the last or Würmian Glaciation, but it is necessary to suppose that *Homo sapiens* existed in the full perfection of his present physical attributes long before that period, if not in Europe, certainly in Asia and Africa. It seems probable that the main stems of modern man—Negro, Mongoloid, and White—were differentiated from the common *Homo sapiens* stock long before the end of the Pleistocene period. I incline to the view that essentially modern types of man existed in Europe before the reign of the Neanderthalers and were responsible for the Chellean and Acheulean cultures, but discreetly withdrew from those chilly areas during the maximum of the last glaciation, leaving the archaic Neanderthalers to shiver in caves and contemplate the glacial moraines.

We have to go back to Neanderthal man to get a human type which is distinctively anthropoid in jaw protrusion and chinlessness. Even this ancient race shows considerable snout reduction, together with rudimentary chin development. No existent type of man probably has descended from the Neanderthaloid species. Neanderthal man was, phylogenetically speaking, an old maid. Furthermore, I consider him an anachronistic survival into late glacial times. The gentleman who owned the Heidelberg jaw, dug up from a depth of some 80 feet in the Mauer sands, was probably an early ancestral Neanderthaler. Some geologists place him in the first interglacial period and others in the second.

The small-brained Sinanthropus skulls, recently dug up near Peking, China, represent in teeth, jaws, and brow ridges possible precursors of the late Neanderthal types. The actual specimens recovered seem to be of Lower Pleistocene date, but the type itself must have developed long before. In Neanderthal man the brain was virtually of modern size and the foot an essentially human, supporting, non-prehensile organ. Forms probably ancestral to the Neanderthalers and assigned to Lower Pleistocene strata exhibit only slightly larger jaws, with slightly more rudimentary chins and somewhat less capacious brains.

The lady from Piltdown Common, England, *Eoanthropus Dawsoni*, burst upon us in 1912 with a virtually full-blown human brain and an almost completely chimpanzee jaw. While she may have lasted into the Lower Pleistocene, she is almost certainly the superannuated survival of a Pliocene type. She leads us to the conclusion that the human brain in some progressive stocks had attained its modern size by the beginning of the glacial epoch, although jaw reduction had scarcely begun. We do not know the Piltdown lady's feet, but we may be reasonably certain that they were not prehensile.

Pithecanthropus erectus of Java is anatomically the most archaic humanoid type. He is referred to the Lower Pleistocene of Java, but should represent the survival of an Early Pliocene or Late Miocene type. His brain was halfway down to giant anthropoid size, his jaws and teeth a little more than halfway human, his thigh bone completely that of a man. He must have walked erect on his hind legs, supported by non-prehensile feet. The human type of foot, posture, and gait may well have evolved by the end of Miocene times.

In the Middle and Upper Miocene period, we have encountered no skeletal remains of man or of humanoid types, but only generalized giant anthropoids, especially of the Dryopithecus family. According to the opinion of Professor W. K. Gregory, which I share, man was probably differentiated from a generalized and progressive Dryopithecus-like anthropoid, either in the Middle or Upper Miocene period. It is then, in our opinion, that a giant primate took to the ground, stood upon his hind legs and took the crucial step toward humanity. We must not picture him at this adolescent stage "standing with reluctant feet where the brook and river meet," but wading boldly in, not without splashing.

A little band of wilful anthropologists insists upon deriving man from some diminutive ground-dwelling Oligocene primate, apparently desiring to refer to the most remote time possible our ignominious identity with the anthropoid apes. I do not believe in this scuttling homunculus, too slow to escape by fleetness, too weak to win through by combat, and too stupid to survive by wit.

We need at least the full range of the Pleistocene and Pliocene periods to allow sufficient time for man to develop from a terrestrial erect anthropoid to his modern human status. There is no evidence for an unduly rapid evolution of human stocks. The process was multiple, involving many different lines, developing asymmetrically, at different rates of speed, and to varying degrees of removal from the anthropoidal status. Many, if not most, of these stocks became extinct. One or more have survived in modern races of man.

On the radioactive twelve-hour clock of man's physical evolution we may represent the elapsed time at seven million years, if we accept Dr. Reeds' estimate of six million years for the duration of the Pliocene period, and let man start with a supporting non-prehensile foot. Born with this essentially human member at 12 o'clock noon, he must have acquired his full brain size at about 10.17 P. M. (end of the Pliocene) and his

straight profile and jutting chin at 11.08 and 34 seconds P. M., or thereabouts (mid-Pleistocene times). It was nearly 11.59 before he began to tame wild animals, to plant, to hoe the garden, and to become domesticated.

I think that at the end of the Secondary Era, the earth was becoming tired of reptiles, irritated with their scales, and fed up with their eggs—especially, perhaps, dinosaur eggs. Then came the lively lemurs, the pop-eyed, hopping tarsiers, the amusing monkey tree-dwellers, and the mighty brachiating anthropoids. One of these last, endowed with a better brain and with a super-primate initiative, sought a richer and more abundant life upon the ground. From him, in the fulness of time, there developed man, with his stable foot, his sensitive prehensile hand, and his great receptive brain. Some men are born to sit aloft in observatories investigating the fulness of the universe. Others are born to sit on the top of flagpoles, contemplating the emptiness of their stomachs. None need be ashamed to have sprung from an ape.

THE MEASUREMENT OF GEOLOGICAL TIME

By Dr. ALFRED C. LANE
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(*Abstract*)

GEOLOGY and astronomy have common interests. Astronomy depends for its observation of great distances on a base line—the diameter of the orbit of the earth. The knowledge of this quantity is based on the size of the earth, which, in turn, rests on some small base line determined by the geodetic survey. The astronomer's light year rests on measurements of a short distance on our earth.

In the measurement of time the same is true. Measurements of great periods of time are founded on a base line of short duration. The Harvard collection of plates, which this building has been constructed to house, reached further back in time than any other. De Sitter once said: "Theories change every month, but a good observation lasts."

The geologist, like the astronomer, measures a great period of time by observations made over a very short time. A group of 50,000 observations has just been completed to determine the exact speed of the decay of radium. Helium content has been measured by Paneth and Urry in quantities as small as one hundredth of a cubic centimeter per ton, in rocks and meteorites. Such measures give us a time scale, and help both geologists and astronomers to fix events in the past and in the future from a relatively short base line.

THE AGE OF THE ROCKS

By Professor ARTHUR HOLMES
DURHAM UNIVERSITY

(*Abstract*)

THE elements uranium and thorium may be regarded as natural clocks, ticking out helium at regular intervals, and providing, in their lead content, a record of the amount of disintegration that has gone on, and hence of the age of the corresponding strata.

Determinations of lead content have led to estimates of sixty million years

for certain Tertiary rocks, and as much as 1,460 million years for some Pre-Cambrian rocks. More recently it has been found that pitchblende from Great Bear Lake has also an age of 1,460 million years, and that a specimen from Manitoba is 1,800 million years old. It is noteworthy that the three greatest recorded ages occur in North America, at points lying roughly on a north-and-south line.

From these results the lower limit of 1,800 to 2,000 million years may be given for the age of the rocks; and the earth must be at least as old as this.

The new time scale makes it possible to give the approximate lengths of successive geological periods. It also enables us to correlate past happenings on different parts of the surface of the globe, and a beginning has been made in piecing together a chronological history of the past.

In addition to estimates based on the amount of lead left from radioactive disintegration (a method inapplicable to rocks that have a high lead content of their own), the method of estimating the age of rocks by the amount of occluded helium (the remains of products of radioactive disintegration) has also wide applications. As some of the helium is bound to be lost, this method always gives lower values for the age than the method based on the lead ratio.

The helium method is applicable to basaltic rocks, and has, for instance, been applied to specimens from the geologically and historically interesting Whin Sill, in England, and to the Tertiary dykes associated with the volcano of Mull, in Scotland. The ages derived from analyses of the helium content of igneous rocks range from 28 million to 500 million years.

The work just referred to is still in its initial stages. It is hoped that the results of further researches of the same kind will lead to important knowledge in the chronology of the earth's surface, with their bearing on the age of the surface of the earth, and of the earth itself.

STABILITY OF THE SOLAR SYSTEM

By Dr. ERNEST W. BROWN

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(*Abstract*)

At the end of the eighteenth century, the French astronomer Laplace proved that a system of planets moving around the sun in definite orbits might suffer many serious disturbances, but still would always hold together. Laplace's statement involved certain approximations which, though legitimate at the time, can now no longer be accepted. Geologists place the birth of our solar system about two thousand million years back, and the approximations of Laplace are justifiable over a period of fifty million years at the very best.

The observational problem of tracing back the paths of the planets over such enormous intervals of time is very difficult. It can be proved definitely that the present observational uncertainties in the planetary orbits are so large that the astronomer can neither predict where a planet will be two thousand million years hence, nor trace back the planet's orbit with any degree of accuracy over such an interval of time. Attempts have been made to discuss the stability by general mathematical methods, but since it is impossible to take all necessary factors into account, one can have little confidence in the result obtained from an application of these methods to our solar system.

Conclusions drawn from individual orbits of certain planets are not generally to be relied on. There are more possibilities in a statistical discussion of the orbits of the small planets moving between Mars and Jupiter (the asteroids, more than a thousand of which are now known). But on account of both the mathematical and the observational difficulties involved it is impossible to make at present any definite statement about the ultimate stability of our solar system, deduced from the law of gravitation and the present configuration.

METEORITES AND THE AGE OF THE UNIVERSE[3]

By Professor ERNST ÖPIK
UNIVERSITY OF TARTU

(*Abstract*)

From the relative content of helium and radium, Professor Paneth in Königsberg has determined the age of a number of meteorites; for 24 different iron meteorites he found values ranging from 100 to 2,900 million years; for the Pultusk stone meteorites, the fall of which in 1868 had been well observed, he gave a preliminary value of 500 million years, which is probably a minimum value because of possible loss of helium in space, and in our museums for over 60 years. The Pultusk meteorite was certainly of interstellar origin, and judging from preliminary results of the Arizona meteor expedition, we may expect that at least several of the iron meteorites investigated by Paneth also did not belong to the solar system. That the age of all these objects is below 3,000 million years suggests a low age also for the stellar universe. This conclusion is strongly supported by other facts mentioned below.

Statistics of the distribution of distances and relative magnitudes in wide double stars indicate that since their origin the masses of the stars can not have decreased appreciably, and that the drop in luminosity of the average star of the dwarf branch can not have exceeded half a magnitude since its origin, instead of the expected six magnitudes or more, while the most probable drop in the luminosity is zero.

The distribution of luminosities of stars in globular clusters, notably the presence of high luminosity red supergiants, as pointed out by Shapley, leads practically to the same conclusion, namely, that stars of different spectral classes can not have evolved one from another, but must have been created simultaneously, and that their age is too short for any appreciable evolution to have taken place.

Finally, the observed recession of the spiral nebulae, reflecting the phenomenon of the expanding universe, indicates a possible age for the extragalactic universe of a few thousand million years only. From all these facts we infer that probably the age of our universe does not differ very much from the age of the solar system, and that not very much more than 3,000 million years have elapsed since the spiral nebulae, the stars, and the star-dust (the meteors) were born out of the original parent system, which we call chaos because we do not know much about it.

[3] The complete paper is soon to appear in *Popular Astronomy*.

TIDES IN THE ATMOSPHERE[1]

By J. BARTELS

PROFESSOR OF METEOROLOGY, FORSTHOCHSCHULE OF EBERSWALDE, DOCENT IN GEOPHYSICS, BERLIN UNIVERSITY, RESEARCH ASSOCIATE, CARNEGIE INSTITUTION OF WASHINGTON

THE subject of this lecture is a part of the mechanics of the atmosphere, and I will therefore indicate at the outset how the atmospheric tides are fundamentally related to the main theme of these three lectures, namely, the magnetic field of the Earth and its atmosphere.

That part of the space to which we have direct access is a comparatively thin shell near the Earth's surface. A distance of 25 miles appears small to us if we travel it in horizontal direction, but a greater height than 25 miles has never been reached with any instrument. In this respect the higher regions of the Earth's atmosphere have been just as remote to us as the Moon or the Sun or the stars, and all our knowledge about them is based on the interpretation of various indirect observations. Such studies on the physics of the upper atmosphere have mainly a twofold interest: First, they reveal strong cosmic influences to which only these outermost regions are exposed, while the lower atmosphere in which we live is only indistinctly affected; and, second, the electrical state of these regions makes long-range radio communication possible.

Among the sources of information about the physical phenomena in these outermost layers, observations of terrestrial magnetism are outstanding. Nearly every variation in the Earth's magnetic force is caused by some electric phenomenon in the height, and most of the magnetic records of which Mr. Fleming showed typical examples two weeks ago are, so to say, messages from high altitudes which lend themselves to suitable interpretation. This holds for the irregular variations during magnetic storms and aurorae which Dr. Kennelly has discussed in his lecture, and particularly for the regular magnetic variations which follow the daily course of Sun and Moon. Indeed, as early as 1878, Balfour Stewart concluded from a discussion of these daily magnetic variations that they originate in the upper atmospheric layers, and that the air in these layers must conduct electricity much better than the air near the ground—a famous scientific hypothesis which was fully confirmed, over 20 years later, after the invention of wireless communication. Balfour Stewart also pointed out that the ultimate cause of the regular daily magnetic variations were atmospheric oscillations of the character of tidal motions. If, for instance, the moon would not perform, day by day, on the Earth's atmosphere that large-scale experiment that results in the lunar atmospheric tide, then we should not observe a certain kind of delicate magnetic variations and should lose, with them, a unique opportunity to study significant changes in the electrical state of the upper atmosphere. The outcome of these systematic experiments of Sun and Moon have been continually watched for many years by a number of magnetic observatories under varying conditions of season, number of sunspots, magnetic activity, distance and relative position of the Moon, and so on. The re-

[1] The third in a series of three lectures concerning the magnetic field of the Earth and its atmosphere delivered at the Carnegie Institution of Washington, March 22, 1932.

sults of the discussion have already been of great interest and will be amplified by the reduction of the data from the two magnetic observatories of this institution, which, because of their geographical locations, are specially favorable for research of this kind. While the detailed theory is fairly complicated and will not be outlined here, you will see now why the tides of the atmosphere have lately been studied more by the magneticians, who use them for the interpretation of their magnetic data, than by the meteorologists, who in fact find the tides rather tedious and of no use for explaining or forecasting the weather.

Let us now speak of the tides themselves. We think naturally at once of the regular rise and fall of the water on the seashore, twice daily, and of the corresponding tidal water-currents. These are familiar effects of the tidal forces which Moon and Sun exert on our planet. We can describe these forces as tending to stretch the Earth in the direction of the line drawn between Earth and Moon, or Earth and Sun, and while the solid Earth yields only partly to these stresses, the sea-water is fairly free to follow them. The influence of the Moon is about twice as great as that of the Sun, and since the Moon attains every day her greatest altitude in the sky about 50 minutes later than on the preceding day, the times of high water on the seacoast are about as much retarded from day to day.

Air is about a thousand times lighter than water, but it has a certain mass and is therefore subject to gravitational attraction—we can say fortunately, because otherwise the air would long ago have diffused into space, and the Earth would be as barren as the Moon whose mass is too small to hold an atmosphere. Just as the air is attracted to the Earth, it must also, like the sea-water, follow the tidal forces, because they have their origin in gravitation. But how can we hope to verify this theoretical conclusion, in other words, how can we observe these tidal effects in the air? There is no coast from which we could watch the tides. One could think of detecting the atmospheric tides in the wind-changes which would be equivalent to the tidal currents in the ocean, but the wind is mostly locally distributed by varying friction since we live at the bottom of the air-ocean. At last we find in the barometer a suitable instrument. Under ordinary meteorological circumstances, namely, the weight of the mercury-column in a barometer is equal to the weight of an air-column of the same cross-section (Fig. 1). So, except during heavy storms or hurricanes, the pressure, as read on the barometer, is a measure of the mass of the air over the station; if we apply the usual barometer-corrections, we can indicate the pressure, the weight of the mercury-column, simply by the length of that column expressed in inches (about 30) or, more convenient for our purposes, in millimeters (about 760).

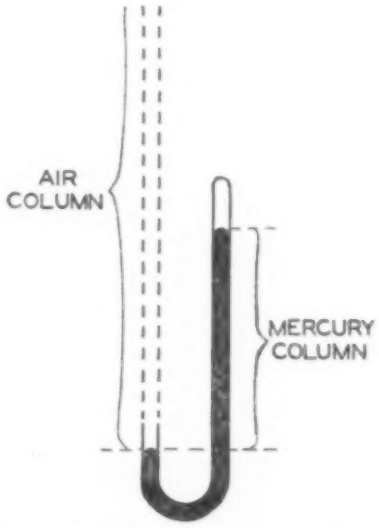


FIG. 1. BAROMETER WEIGHS ATMOSPHERE.

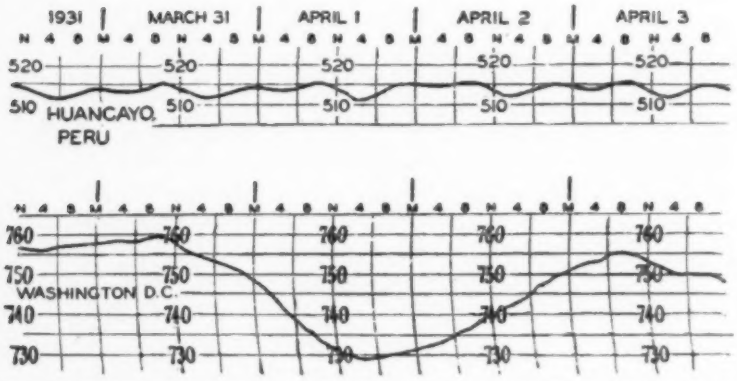


FIG. 2. BAROGRAPH CURVES AT HUANCAYO, PERU, AND WASHINGTON, D. C.

Continuous records of barometric pressure are given by the barographs, and in these curves we ought to look for tidal effects. Fig. 2 shows typical original records for the same day for two stations, one in the tropics, one in temperate latitudes. The contrast is obvious: At Washington we find the long waves connected with the weather changes during the passage of areas of high and low pressure; at first sight no systematic daily influence, no diurnal variation at all can be discerned. At Huancayo, however, we see day by day a regular double wave with the main maximum and minimum at 10 A. M. and 4 P. M., and secondary maximum and minimum at 10 P. M. and 4 A. M. (The low mean value of the pressure, 512 mm, at Huancayo is due to the altitude of our observatory, 11,000 feet above sea-level.) This regular phenomenon has been known more than 250 years and is observed everywhere in the tropics on land or sea, that is, on nearly half of the Earth's surface. The regular rise and fall of the pressure in the tropics is practically independent of the weather, only hurricanes can interrupt it. It also changes little with season, as the average diurnal curves for the months show for Key West in Florida (Fig. 3).

We are reminded of tides, because there is twice daily high pressure, and twice low pressure, but these maxima and minima occur every day at the same local time, at 10 and at 4 o'clock, and are not retarded from day to day as the ocean-tides. So they can not be related to the Moon, but must be produced by the Sun. However, they can not be simply the tides produced by the Sun, because we should then expect the maxima about noon and midnight or somewhat later, but not two hours *earlier* at 10 o'clock. Another possible cause might be the Sun's radiation, which results in the heating of the air in daytime and

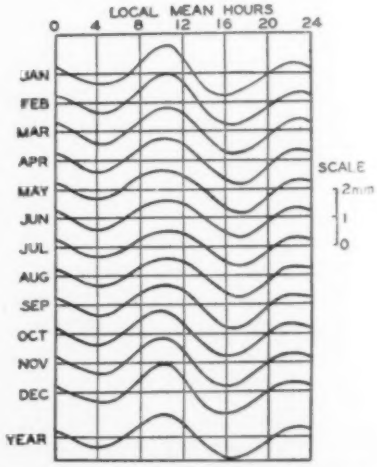
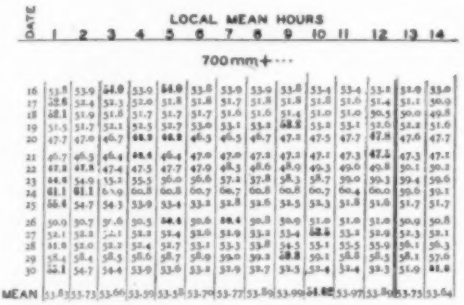


FIG. 3. DIURNAL VARIATION OF PRESSURE, KEY WEST, FLORIDA (AFTER HUMPHREYS).

the cooling at night, but this is essentially a single wave, per day, with one maximum of the temperature in the afternoon, and one minimum in the morning before sunrise, and it is hard to see how such a single wave could produce a double wave in pressure.

In order to approach this famous question, we shall analyze the barograph-records more closely and shall start with reading from these barograph-curves the values of pressure hour by hour (Fig. 4). These tabulations are, so to say, our raw material. From all the hourly values in a certain month we can form the average of all the observations taken at midnight, then those at 1 A. M., etc. In this way we derive an average variation of pressure throughout the day, the diurnal variation. These are shown in Fig. 5 for Washington, D. C., in an average for the months with the shortest days (December-January) and in an average for the months with the longest days (June–July); 14 years of observations were used. Both curves show high pressure in the forenoon, low pressure in the afternoon; the variation in the night-hours is much smaller than in the daylight-hours.

By a simple mathematical process we can represent these diurnal curves as the sum, as the superposition, of a number of curves of very simple form, so-called sine-waves. All sine-waves have similar forms. They are mainly distin-



DATE	LOCAL MEAN HOURS 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	700 mm + ···													
16	53.8	53.9	54.0	53.9	54.0	53.8	53.9	53.9	53.8	53.4	53.4	53.2	53.0	53.0
17	52.6	52.4	52.3	52.0	51.8	51.8	51.7	51.8	51.8	51.8	51.6	51.4	51.1	50.9
18	50.1	51.9	51.8	51.7	51.7	51.7	51.6	51.6	51.4	51.0	51.0	50.5	50.0	49.8
19	51.5	51.7	52.1	52.5	52.7	53.0	53.1	53.2	53.5	53.2	53.1	52.6	52.2	51.6
20	47.7	47.9	48.7	48.9	48.8	48.3	48.5	48.7	47.2	47.5	47.7	47.8	47.6	47.7
21	46.7	46.3	46.4	46.6	46.4	47.0	47.0	47.2	47.2	47.1	47.3	47.5	47.3	47.1
22	47.8	47.8	47.4	47.5	47.7	47.9	48.3	48.6	48.9	49.3	49.6	49.8	50.1	50.2
23	54.6	54.9	55.2	55.5	56.0	56.6	57.2	57.8	58.3	58.7	59.0	59.3	59.4	59.6
24	61.1	61.1	61.9	60.8	60.8	60.7	60.7	60.8	60.8	60.7	60.4	60.0	59.6	59.1
25	56.6	56.7	56.3	55.9	55.4	55.2	55.0	54.8	54.6	54.5	54.3	54.2	54.1	54.0
26	50.9	50.7	50.6	50.5	50.4	50.6	50.8	50.8	50.9	51.0	51.0	51.0	50.9	50.8
27	52.1	52.2	52.1	52.2	52.4	52.6	52.9	53.2	53.4	53.6	53.2	52.9	52.3	52.1
28	51.0	52.0	53.2	53.4	52.7	53.1	53.3	53.8	54.5	55.1	55.5	55.9	56.1	56.3
29	55.4	55.4	56.5	56.6	56.7	56.6	56.6	56.9	57.2	57.8	58.1	58.3	58.1	57.6
30	56.1	56.7	56.4	53.9	53.6	53.2	52.9	52.7	52.5	52.4	52.4	52.3	51.9	51.6
MEAN	53.8	53.73	53.66	53.50	53.58	53.72	53.77	53.80	53.99	54.02	53.97	53.80	53.75	53.64

FIG. 4. SPECIMEN OF HOURLY TABULATIONS OF AIR-PRESSURE, SEPTEMBER 16–30, 1930, AT POTSDAM, GERMANY.

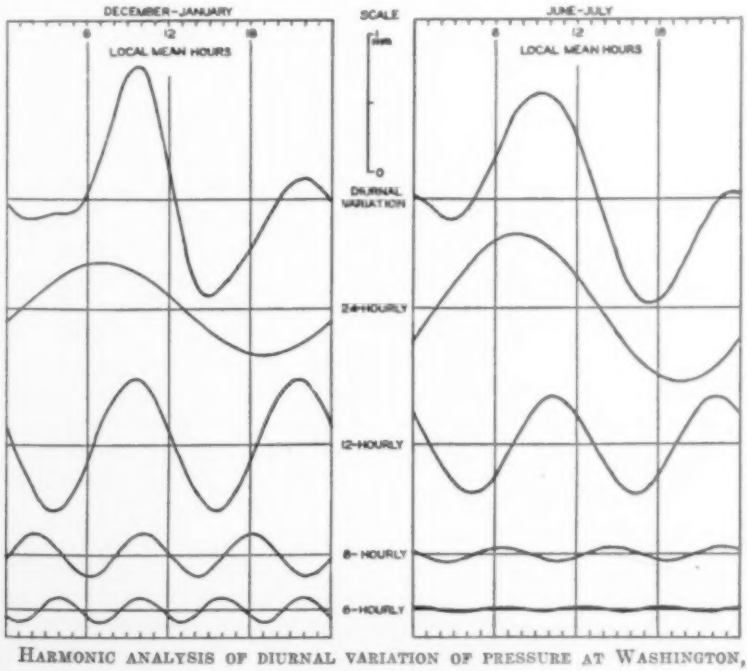


FIG. 5. HARMONIC ANALYSIS OF DIURNAL VARIATION OF PRESSURE AT WASHINGTON, D. C.

guished by their periods, that is, the times in which they complete a full wave or cycle (here 24, 12, 8 and 6 hours, respectively); and sine-waves of the same period are characterized by their amplitude, that is, their greatest deviation from the mean line, and by the time of occurrence of their maximum. The decomposition of a diurnal variation into sine-waves with the periods of a full day, half a day, one third, one fourth of a day, etc., is called harmonic analysis; it would be possible to find also sine-waves of smaller periods of one fifth of a day, etc., but that is in general unnecessary, since the superposition of the first four sine-waves already approximates the diurnal variation sufficiently well.

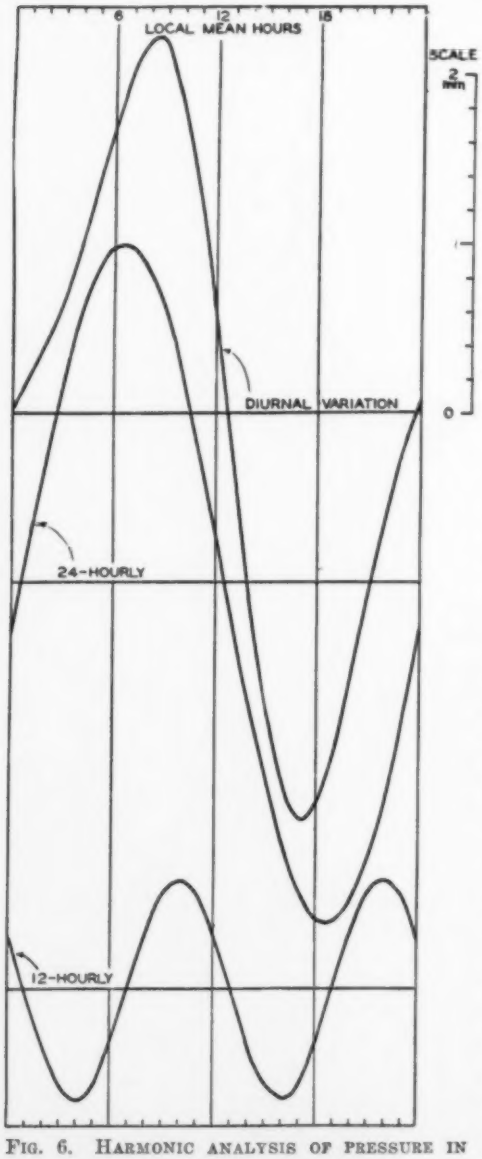


FIG. 6. HARMONIC ANALYSIS OF PRESSURE IN SUMMER, DEATH VALLEY, CALIFORNIA.

The process of harmonic analysis is entirely formal, mathematical, and can be applied to any curve. If, for instance, we should find pleasure in counting the number of people crossing 12th Street on F Street per hour, we might also derive a diurnal variation, this curve could also be subjected to harmonic analysis, but this would be nothing but a mathematical amusement. The reason why we apply harmonic analysis to pressure observations is mainly that theory leads us to expect sine-waves in the oscillations of the atmosphere, just as sine-waves appear in every other physical phenomenon of oscillation. Such physical phenomena are abundant in number; in fact, when we listen to a radio program, our ear combines millions of different acoustic sine-waves. These are transmitted by a still greater number of electromagnetic sine-waves which pervade the space in such a multitude that we can only be glad that they do not act directly on any of our senses and turn us into nervous wrecks.

We may at once realize the advantage of harmonic analysis when we notice that the twelve-hourly sine-wave in pressure at Washington is nearly the same in winter and summer, with maxima at 10 o'clock in the morning and evening, minima at 4 o'clock in the morning and afternoon. So we have found again the tropical double wave, which is only hidden in the diurnal variation by other waves. The 24-hourly wave has larger amplitudes in summer than in winter, with the maximum about

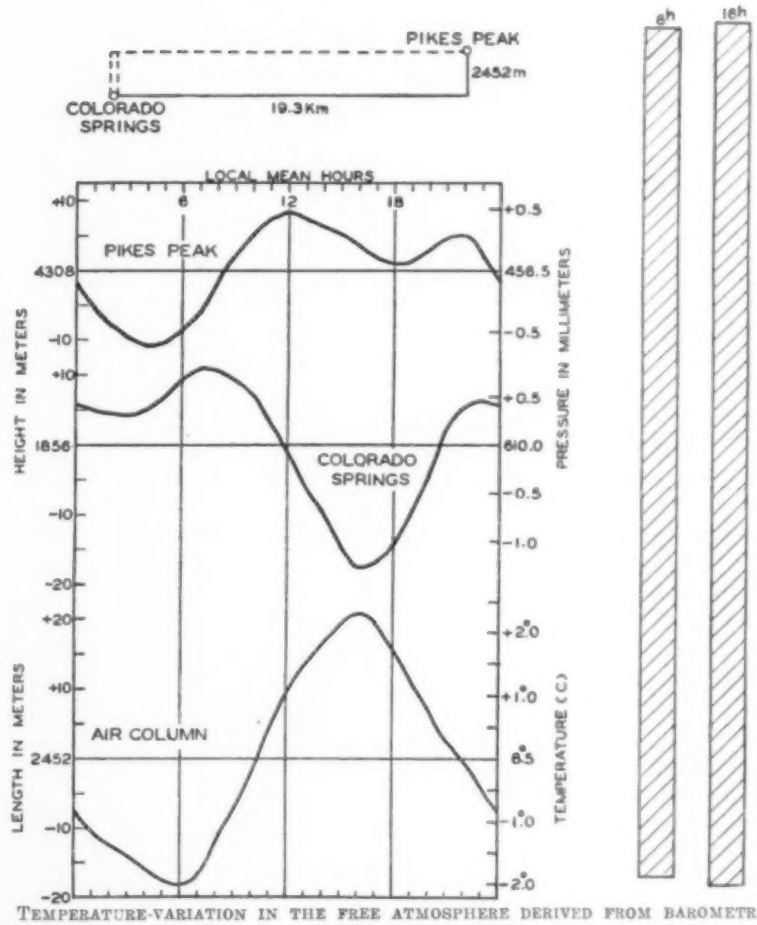


FIG. 7. TEMPERATURE-VARIATION IN THE FREE ATMOSPHERE DERIVED FROM BAROMETRIC OBSERVATIONS.

6 o'clock in the morning. The 8-hourly wave is interesting because in winter it has its first maximum about 2 o'clock, but in summer its first minimum at the same time; the crests and troughs of the 8-hourly wave have reversed their places from winter to summer.

Some examples will show the great differences in the diurnal variation of pressure at different stations. The diurnal variation is especially pronounced at the bottom of valleys; at Death Valley in California, the pressure in summer at 5 P. M. is 4.6 mm smaller than at 8 A. M. (Fig. 6). Harmonic analysis finds the 24-hourly wave responsible, while the 12-hourly wave is again quite normal as to amplitude and time of maximum.

Next we consider the summer conditions on top of a mountain (Pike's Peak) and at a base-station (Colorado Springs); the relative position of the two stations is indicated in the small vertical section at the top of Fig. 7. The diurnal variations of pressure, as shown in the two upper curves, look very different.

We can account for this difference in the following way: Consider a barometer at a fixed height. At a certain time it may indicate a pressure of 750 mm. We know that pressure increases downward and decreases upward in the

atmosphere. If, therefore, the reading of the barometer after some time rises to 751 mm, we can find vertically above the station a level where the pressure is 750 mm, and if our fixed barometer falls below 750 mm, we can find the pressure 750 mm at some lower level. In other words, every rise and fall in the reading of a barometer can be expressed as the rise or fall of the level where the pressure has a given constant value.

The two upper curves in Fig. 7 can therefore be interpreted in two ways—either using the scales on the right, as diurnal variations of pressure in the fixed heights 4,308 m and 1,856 m above sea-level, or, using the scales on the left, as the diurnal rise and fall of the levels of constant pressure 456.5 mm and 610.0 mm. These levels of constant pressure are so nearly horizontal that the data for Pike's Peak can be considered as a good approximation for the conditions in the free atmosphere over Colorado Springs. The two curves represent, therefore, the vertical movements of the upper and lower levels of a certain vertical air-column in the course of a day. Remembering that the barometer weighs the atmosphere, we see that the total mass M of air above the bottom level of the column must be constant (corresponding to the constant pressure 610.0 mm), and also the total mass m of air above the top level of the column (corresponding to the constant pressure 456.5 mm); consequently, the mass of the air $(M-m)$ in the column also must be constant. The third curve in Fig. 7, which is the difference of the two upper curves, represents therefore the changes in the length of this column throughout the day. It is, on the average, 2,452 m long, but at 6 A. M. it is 18.0 m shorter, and at 4 P. M. it is 20.7 m longer, as shown to scale in the two columns sketched in the right-hand part of the diagram. These contractions and dilatations of the column can only be interpreted as corresponding changes in the mean temperature of the air in the column because, as we have seen, the column contains always the same mass of air. This is done by the scale at the right of the lower curve; the column which, on the average, has the temperature 8.°5 C. is 2.°0 C. cooler at 6 A. M., and 2.°3 C. warmer at 4 P. M. We have thus obtained from barograph-readings an estimate for the variation of the temperature in the free air between the levels of the two stations on top and at the foot of Pike's Peak—and a very reliable estimate it is, which could not be as readily deduced from direct balloon-observations of temperature.

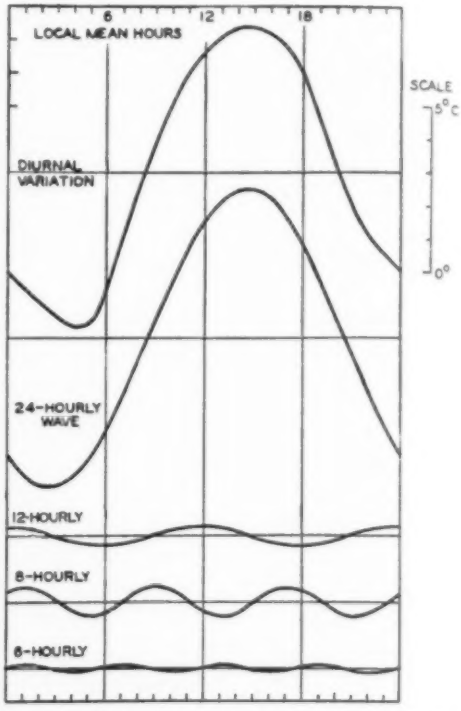


FIG. 8. HARMONIC ANALYSIS OF AIR-TEMPERATURE IN JUNE AT POTSDAM, GERMANY.

I have treated this simple calculation at some length here, because its plausible result incidentally supports our rule on which the calculation was based, namely,

that the barometer weighs the atmosphere. This has sometimes not been realized, and just recently (in connection with the absorption of the penetrating radiation by the atmosphere) the question has been revived in its simplest form. Consider two balloons full of air, one hermetically closed, the other with an opening. If these balloons are heated, the pressure in the closed balloon will rise and the rubber will burst eventually, but in the open balloon the pressure remains practically the same since the air can expand freely and flow out. The conditions of the atmosphere at sunrise have been compared to those in the closed balloon; it has been said that the Earth is so rapidly heated in the morning that the air (partially confined, because of its viscosity and inertia), can not expand fast enough, and the pressure rises simply because of the heating. This was offered as an explanation of the morning maximum of pressure. This opinion may, however, be proved to be wrong; the atmosphere corresponds to the air in the open balloon, because it can expand vertically fast enough and can adjust itself to the diurnal variation of temperature. Diurnal variations of pressure are really only due to corresponding changes in the weight of the atmosphere above the station, and such changes in the weight can only occur through horizontal movements of air, that is, through winds. These winds—land- and sea-breeze, mountain- and valley-breeze—may be too weak to be noticeable every day, but the systematic shift of air-masses is sufficient to be recorded by the barometer and to be brought forth in the average of many days. Since these winds are mainly local in character and depend mostly on the differential heating of different parts of the Earth's surface—land and sea, for instance—they will have a diurnal variation which is similar to that of their cause, the temperature of the air; that is, mainly a 24-hourly wave as shown in Fig. 8. This explains why the local differences in the diurnal variations of pressure are confined to the 24-hourly sine-wave, but scarcely affect the 12-hourly sine-wave.

This distinction is again brought out in Fig. 9, both on Pike's Peak and at Colorado Springs the 12-hourly pres-

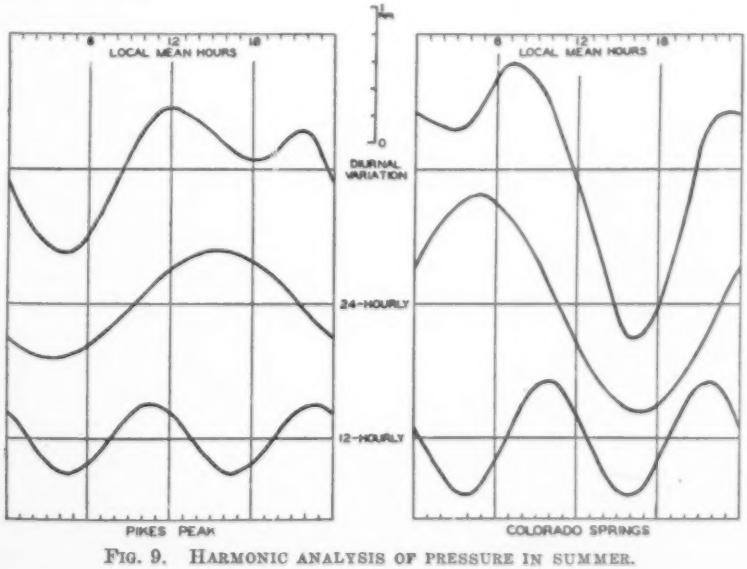


FIG. 9. HARMONIC ANALYSIS OF PRESSURE IN SUMMER.

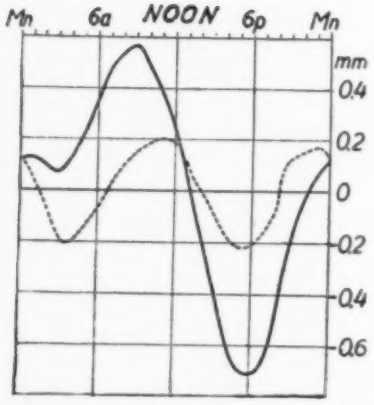


FIG. 10. DIURNAL VARIATION OF PRESSURE ON CLEAR (FULL LINE) AND CLOUDY DAYS IN JUNE AT POTSDAM, GERMANY (AFTER WIEN-HARMS).

sure-wave has its maximum near 10 o'clock in the morning and in the evening, while the 24-hour waves on the top and at the foot of the mountain are exactly reversed.

The mainly local character of the 24-hourly wave of pressure as against the universal character of the 12-hourly wave can finally be ascertained in the following way: On cloudy days, the diurnal variation of temperature is small as compared with clear days. Consequently, the shift of air between land and sea and the accompanying winds and variations of pressure will also be smaller on cloudy days. This is shown in Fig. 10; on clear days, there is only one maximum and one minimum in pressure, but, on overcast days, all local effects are diminished, and only the world-wide 12-hourly wave of pressure persists. Fig. 10, simple as it looks, is the only reliable curve of its kind which has ever been derived, because the numerous other attempts have been badly spoiled by a curious systematic curvature-effect which is connected with the selection of clear and cloudy days and has always been overlooked.

It would be tedious to show the universal character of the 12-hourly wave of pressure by more curves of the same kind. A more convenient way of representing sine-waves is explained in Fig. 11. It shows the 12-hourly wave of pressure at Washington, D. C., in winter, above in the usual way, below in the so-called harmonic dial. This is nothing but a graph of the dial of an alarm-clock, in which the hand points towards the time of maximum, while the amplitude of the wave is indicated by the hand. This simple graph replaces the curve in every way, because the form of a 12-hourly sine-wave is completely given if we know its amplitude and time

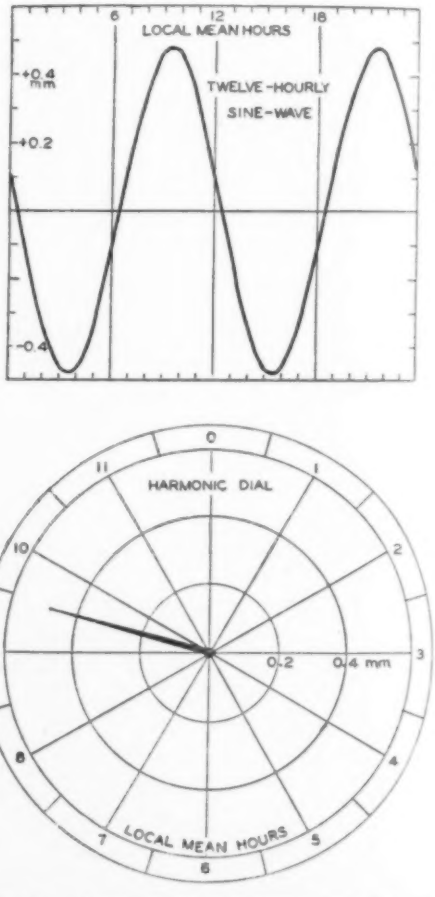


FIG. 11. ATMOSPHERIC PRESSURE FOR DECEMBER AND JANUARY, WASHINGTON, D. C.

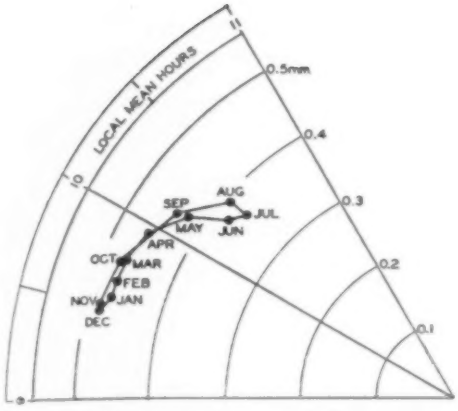


FIG. 12. HARMONIC DIAL FOR TWELVE-HOURLY WAVES OF PRESSURE, WASHINGTON, D. C.

of maximum. The harmonic dial can be further simplified by indicating the hand only by its end-point; it has then the advantage that more than one wave can be shown on the same dial. We can further omit unnecessary parts of the dial. This has been done in Fig. 12, which shows the 12-hourly waves of pressure at Washington, D. C., for every month. Only the end-points of the hands for each month are drawn and counted in succession; throughout the year, the maximum occurs between 9^h 30^m and 10^h 30^m, and the amplitude remains about 0.4 mm.

In the chart of North America (Fig. 13), harmonic dials are imagined with their center at all those meteorological stations for which the 12-hourly (or semi-diurnal) wave of pressure, in the average for the whole year, has been computed from actual observations; only the hands of the dial are shown. The amplitude diminishes from the tropical regions towards the north (from 0.9 mm in the West Indies to 0.3 mm at Cleveland and Chicago), but the maxima occur everywhere with astonishing regularity about 10 o'clock local time. Using the conception of the harmonic dial as an alarm-clock which rings at the time of the maxima, we should hear the alarm 2 hours before noon and 2 hours before midnight, progressing from east to west across the continent with a speed of about 800 miles per hour—much faster than any cyclone.

In the schematic world-chart (Fig. 14), this progressive 12-hourly wave is represented by isobars, that is, lines of

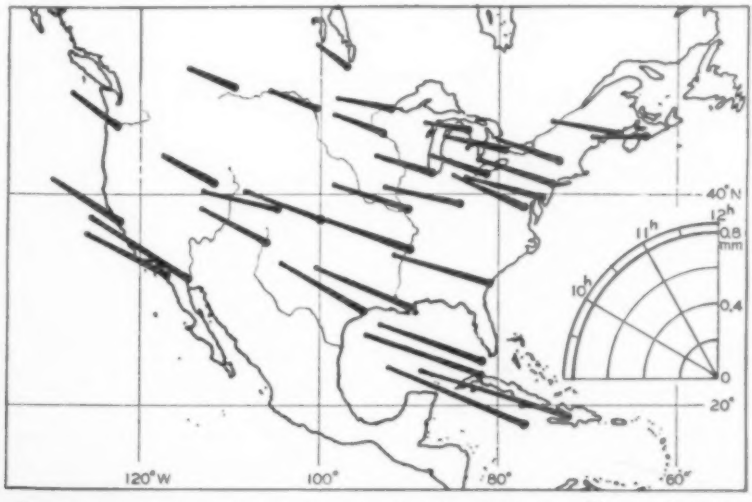


FIG. 13. SEMI-DIURNAL SOLAR WAVES OF ATMOSPHERIC PRESSURE IN NORTH AMERICA: SCHEME FOR HARMONIC DIAL SHOWN BY INSET.

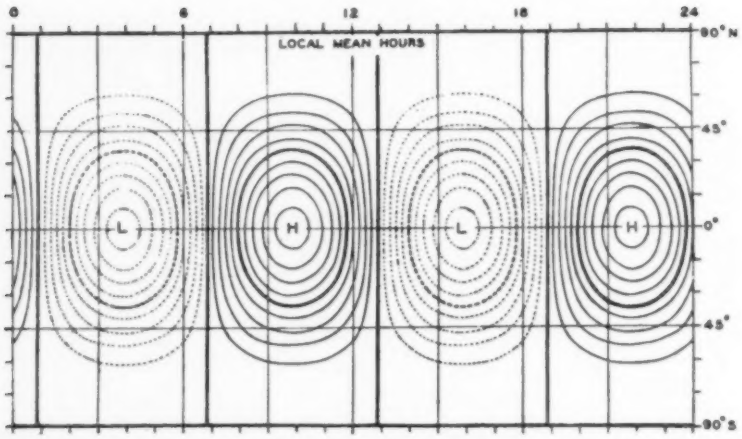


FIG. 14. WORLD CHART OF PROGRESSIVE TWELVE-HOURLY WAVE—ISOBARS 0.1 MM DISTANT (FROM NATURWISSENSCHAFTEN).

equal pressure, drawn 0.1 mm apart; as in a weather-chart, we recognize two areas of high pressure (H), centered at the equatorial points where the time is $9^h\ 50^m$ in the morning and evening, and two areas of low pressure (L) at $3^h\ 50^m$. This double wave travels with the Sun from east to west. The chart shows how the amplitudes decrease towards the poles, from nearly 1.0 mm at the equator to 0.1 mm in 60° latitude.

In the polar caps, the 12-hourly wave is very small and seems irregular. In the harmonic dial, on the left in Fig. 15, the values of the 12-hourly pressure-wave for the polar stations north of 70° north are marked by small circles, and those for polar stations south of 65° south by small crosses. The maxima are scattered all over the dial, instead of occurring about 10 o'clock as we have seen for non-polar stations. This irregularity is, however, only apparent and turns into a striking regularity if we use, not the dial of local time, but one of universal time, for instance, Greenwich mean time. This transformation is done in the right-hand dial of Fig. 15; as though by magic, all the points arrange themselves about $11^h.5$ Greenwich time. Somewhat idealizing we can say that the alarm-clocks ring in both polar caps simultaneously. The amplitude is about 0.1 mm at the poles.

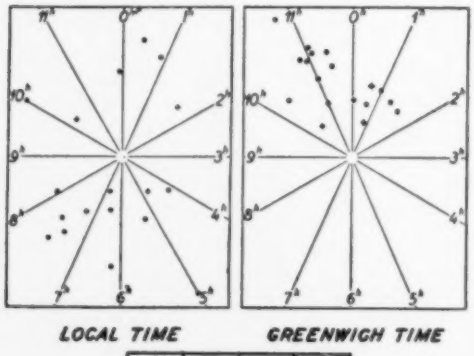


FIG. 15. HARMONIC DIAL OF SEMI-DIURNAL VARIATION OF PRESSURE FOR POLAR STATIONS NORTH OF 70° N. (CIRCLES) AND SOUTH OF 65° S. (CROSSES) (AFTER WIEN-HARMS).

Mathematical analysis can detect this polar wave also at a greater distance from the poles, where it is of course combined with the main progressive wave. An isobar chart of the polar region (Fig. 16) shows zones of high and low pressure; this wave is therefore called zonal. It is stationary, that is, the nodes (in about 35° latitude) remain fixed. The chart shows the conditions at $11^h.5$ Greenwich time (the time of maximum in the polar zones); 3 hours later there

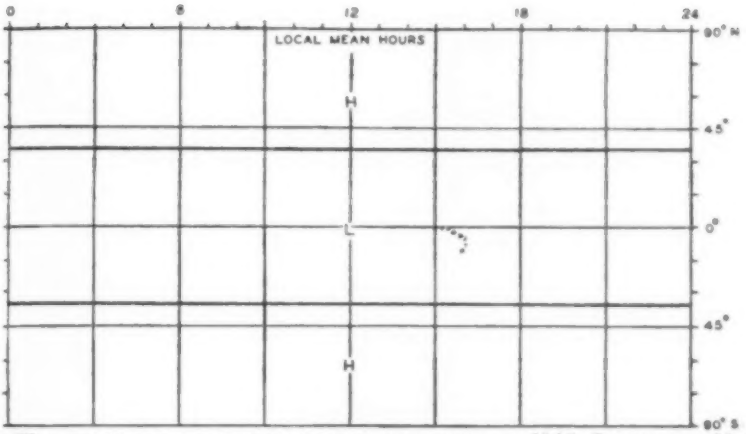


FIG. 16. WORLD CHART OF ZONAL TWELVE-HOURLY WAVE AT 11.h5 GREENWICH MEAN TIME (FROM NATURWISSENSCHAFTEN).

would be no pressure-differences, 6 hours later the polar caps would have low pressure and the equatorial zone high pressure, and 12 hours later the distribution of pressure would be again the same as shown in the figure.

An 8-hourly wave of pressure had long been overlooked, because the theory of the gravitational tides does not predict such a wave. It exists, however, and not merely as a mathematical fiction, but as a separate progressive wave of a strange symmetry. Fig. 17 shows, for two stations in the northern hemisphere, the 8-hourly waves for each month in harmonic dials, which, for economy, have been cut down to the form of wrist-watches, and which show only the times of the first maxima in the day, because the two others occur exactly 8 and 16 hours later. The amplitudes are small, of the order of 0.15 mm, and a bit larger at Washington than at Potsdam, but otherwise the dials for both stations show the same features. In the winter months, the first maximum occurs shortly after 2 o'clock in the morning, the first minimum, therefore, at 6 o'clock. In the summer months, the wave is exactly reversed: We read from the dial that the first maximum of pressure occurs shortly after 6 o'clock in the morning, just the time when the first minimum occurs in winter! We find this reversal from summer to winter again in the 8-hourly wave of temperature (Fig. 18); this indicates a relation of cause and effect between the 8-hourly waves of temperature and pressure which is confirmed by theory.

The world chart for the 8-hourly wave of pressure (Fig. 19) is drawn for December, that is, winter in the northern,

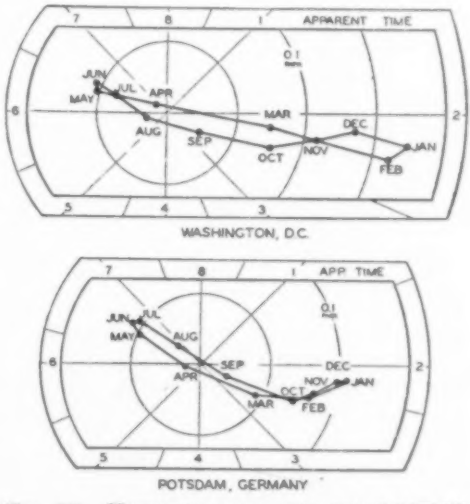


FIG. 17. HARMONIC DIALS FOR EIGHT-HOURLY WAVES OF PRESSURE, WASHINGTON, D. C., AND POTSDAM, GERMANY.

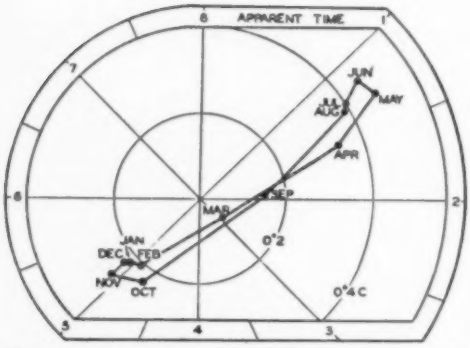


FIG. 18. HARMONIC DIAL FOR EIGHT-HOURLY WAVE OF TEMPERATURE, POTSDAM, GERMANY.

and summer in the southern hemisphere. The areas of high and low pressure are therefore opposite on both sides of the Earth's equator. The amplitude is highest, about 0.15 mm, in 30° latitude. The chart for June would look similar, but the letters *H* and *L* would exchange their places. (This world-chart does not show that the amplitude of the 8-hourly pressure-wave is smaller in summer than in winter; it contains only the relevant part, corresponding to the anti-symmetric spherical harmonic P_4^3. In other words, the monthly means of the waves are not reckoned from the origin of the dial in Fig. 17, but from the center of gravity of the twelve monthly dots, that is, the average for the whole year.)

The horizontal winds near the Earth's surface which accompany the 12- and 8-hourly pressure-waves are shown in the schematic charts in Fig. 20. The isobars in these charts are copies of characteristic parts of the diagrams Figs. 14 and 19. It is interesting to note how the wave-motion progresses towards the west, since all the wind arrows converge to the points where the high pressure will have moved after a quarter of the period (3 or 2 hours). These periodic winds are weak, less than about 2 feet per second, or about one mile per hour. If there were no other winds, an air-particle would describe regular ellipses of about 2 miles extent for the 12-hourly wave, and one third of a mile for the 8-hourly. Similar air-movements in the high layers of the atmosphere are the cause of the magnetic variations which were mentioned at the beginning.

The systematic harmonic analysis has, as we have seen, revealed regular world-wide oscillations of the atmosphere in the solar diurnal-variations of pressure. The search for corresponding influences of the Moon was first successful for tropical stations, but met great difficul-

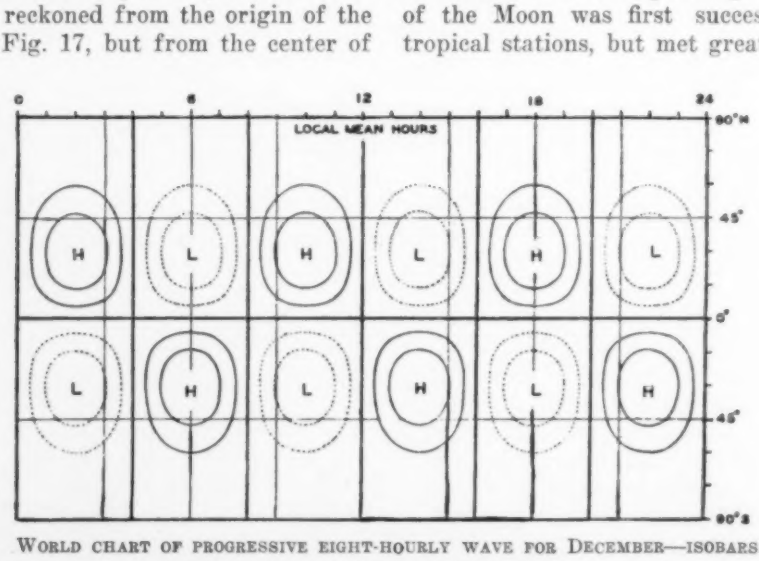


FIG. 19. WORLD CHART OF PROGRESSIVE EIGHT-HOURLY WAVE FOR DECEMBER—ISOBARS 0.5 MM DISTANT (FROM NATURWISSENSCHAFTEN).

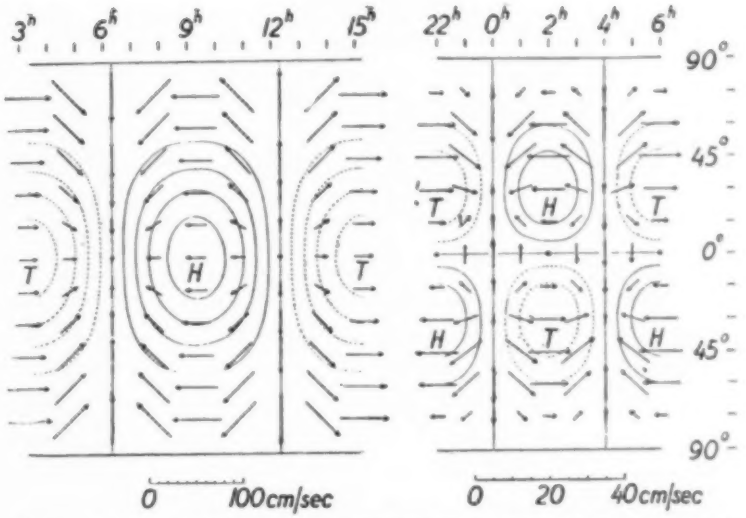


FIG. 20. CHART SHOWING HORIZONTAL AIR-MOVEMENTS IN THE PROGRESSIVE TWELVE-HOURLY (LEFT) AND EIGHT-HOURLY DIURNAL WAVES OF PRESSURE (AFTER WIEN-HARMS).

ties for stations in higher latitudes because of the great unperiodic variations of pressure which are connected with the weather changes. Laplace used nearly 5,000 barometric observations taken through eight years at Brest, and Airy used 160,000 hourly observations taken through twenty years at Greenwich, but both analyses failed, and satisfactory results have been obtained only in recent years, mostly by S. Chapman.

In principle, the calculation of a lunar variation is the same as that of a solar variation. A *solar* day is reckoned from midnight to midnight or, as the astronomers say, from one lower transit of the Sun to the next; the upper transit is noon. In the same way we may introduce a *lunar* day from one lower transit of the Moon to the next, an interval about 50 minutes longer than a solar day. The lunar day can again be divided into 24 lunar hours. Starting from our raw material, the hourly values of pressure for a number of years, we combine all pressure-observations for the first lunar hour, for the second lunar hour, etc. The result derived from 66 years of observations at Potsdam and Hamburg are

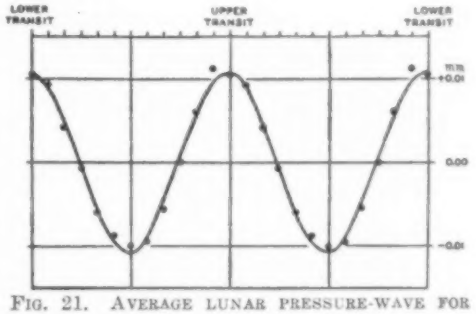


FIG. 21. AVERAGE LUNAR PRESSURE-WAVE FOR POTSDAM AND HAMBURG, GERMANY (FROM NATURWISSENSCHAFTEN).

represented by dots in Fig. 21, which fit into a beautiful sine-wave of 12 lunar hours period, a lunar semi-diurnal wave, with high pressure near the lower and upper transit of the Moon, just as tidal theory predicts. Why it was so difficult to obtain this curve is explained by the extremely small amplitude, 0.01 millimeter; the pressure is only 0.02 mm higher, when the Moon stands highest in the sky or lowest below the horizon than when the Moon is just rising or setting in the horizon. The curve, as it appears in Fig. 21, shows the actual lunar rise and fall of the mercury column of

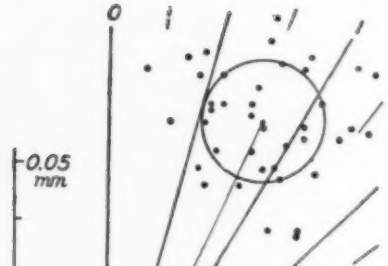
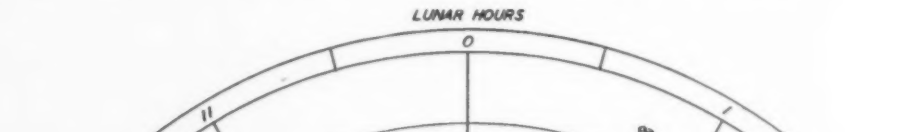


FIG. 22. SEMI-DIURNAL WAVE IN PRESSURE FOR LUNAR HOURS—BATAVIA, 1866–1905 (AFTER WIEN-HARMS).

the barometer, about 1,000 times enlarged. An ordinary barograph-curve of 40 mm width, such as that shown for Washington in Fig. 2, would, on the same scale, be about 120 feet high, and even the trace of the recording pen would appear about 8 inches wide. This minute lunar wave is, so to say, drowned in the large irregular waves of the ordinary high- and low-pressure areas, and its detection is the triumph of certain statistical methods which had to be developed for the discovery of such hidden periodicities. This improvement of the analytical methods which was necessary for the computation of the lunar tides in atmospheric pressure has sharpened the tools with which we may test the great number of other cycles and periods which have been claimed in geophysical and cosmical phenomena.

The computation of the lunar atmospheric tide is also a typical geophysical problem in another direction. The raw material from which the computation starts are readings of the barograph-curves to 0.1 mm such as 759.1 mm; the result is a curve which is accurate to 0.001 mm. It looks as though a higher precision of the original observations—to 0.01 mm, for instance, which is quite feasible—might be helpful. But this



STATION	LAT.
OI—OCEAN ISLAND	0.9 S
Ba—BATAVIA	6.2 S
P —PERIYAKULAM	10.1 N
K —KODAIKANAL	10.2 N
Md—MADRAS	13.1 N
Bo—BOMBAY	18.9 N
Mx—MEXICO	19.4 N

STATION	LAT.
Mr—MAURITIUS	20.1 S
Ho—HONGKONG	22.3 N
He—HELWAN	30.0 N
T —TIFLIS	41.6 N
G —GREENWICH	51.5 N
PH—POTSDAM-HAMBURG	53.0 N
A —ABERDEEN, SCOTLAND	57.9 N

FIG. 23. HARMONIC DIAL FOR THE SEMI-DIURNAL LUNAR WAVE IN PRESSURE AT VARIOUS STATIONS.

idea is fallacious; not the observational errors but the great natural non-periodic variations of pressure hide the lunar wave. The wave can be found only by refining a great number of barometric curves in which it is so highly diluted.

The principle of these statistical methods is indicated in the harmonic dial for the lunar semi-diurnal waves in pressure at Batavia, Fig. 22. Each of the 40 dots represents the result as computed from the observations in one of the 40 years 1866–1905. The amplitude seems to vary between 0.04 and 0.08 mm, and the highest pressure occurred in some years only about 10 minutes, in others as late as one and a half hours after the transit of the Moon (marked on the dial as O'). This scattering of the results for the single years is not to be regarded as a real change in the lunar wave from year to year, since it is only due to the difficulty of eliminating the non-lunar variations of pressure from the observations in a single year; but the amount of scattering provides us with a quantitative estimate for the reliability, the probable error, of the average lunar wave as derived from 40 years of observation.

Fig. 23 contains the results of the analyses of lunar waves in atmospheric pressure to date; in all, it represents the extract of over two millions of hourly observations. In spite of the small amplitudes (decreasing from about 0.06 mm at Batavia near the equator to 0.01 mm at Potsdam, and still less at Greenwich), high pressure occurs everywhere within one hour of the lunar transit. The small individual differences in time of the maximum can be attributed to the fact that the atmosphere is not only under the direct influence of the Moon's tidal forces, but is of course secondarily affected by the tidal movements of its under-surface, ocean and land, and the oceanic tides are locally very different, as is well known.

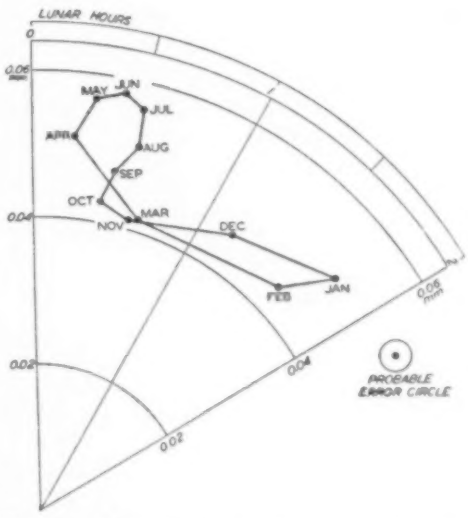


FIG. 24. SEMI-DIURNAL WAVE OF PRESSURE FOR LUNAR HOURS—AVERAGE FOR BATAVIA, BOMBAY, AND HONGKONG.

A puzzling feature of this lunar semi-diurnal wave of pressure of which we just saw the annual averages, is its systematic change in the course of a year, which is surprisingly similar all over the globe. In January, the maximum pressure occurs more than one hour later than in June, and the amplitude is also smaller (Fig. 24). This change is real, because it is far outside the range of the probable-error circles, the size of which is indicated in Fig. 24. Such circles must be imagined to be drawn around

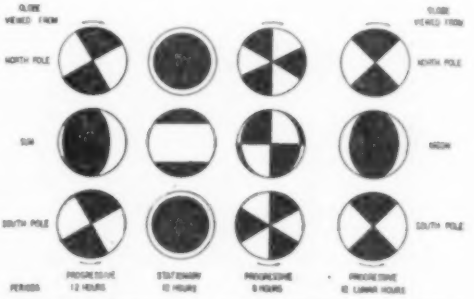


FIG. 25. SCHEME OF WORLD-WIDE OSCILLATIONS OF THE ATMOSPHERE.

each dot representing a monthly value of the lunar wave in the harmonic dial; they indicate, by their small diameter, the reliability of the monthly values, of which each is based upon about 100,000 hourly values.

The lunar wave in atmospheric pressure is one of those rare cases in which nature makes one simple large-scale experiment at a time. The Moon's heat radiation is negligible, so that the whole effect of the Moon is gravitational, truly tidal. Yet, the rise and fall of the air-pressure with the Moon entails also a slight temperature-variation; because, when air is compressed, it gets warmer. An every-day experience of this is that when air is pumped into a car-tire the valve gets hot. The compression and dilatation of the air in the lunar pressure-wave is so small that even for the tropical station Batavia theory predicts only a so-called adiabatic heating by 0.015 degree Centigrade from the lowest to the highest pressure in the lunar wave. Through the reduction of over 60 years of hourly observations of air-temperation at Batavia, this minute temperature-effect has indeed been found, and one may conclude that here in Washington a similar, though smaller, effect exists. In familiar terms, under like weather conditions, here in Washington it is about one fiftieth of a degree Fahrenheit warmer when the Moon stands highest in the sky or lowest below the horizon than when the Moon rises or sets at the horizon. Of course, the temperature-changes which accompany the weather changes are about one thousand times as large; but the lunar wave gives interesting information about the properties of the atmosphere, because it is the only case in which we can study the effect of a pure pressure-change on large air-masses without the vitiating influence of simultaneous changes in radiation.

The problems with which finally an explanation of the tidal atmospheric movements is faced are best formulated in connection with Fig. 25, which summarizes the results of the observations. It shows for each of the world-wide oscillations of the atmosphere, three schematic views of the globe from the north and south poles and from the Sun or Moon; high- and low-pressure areas are indicated in black and white. The main wave is the 12-hourly progressive solar wave, with maxima at 10 o'clock; it is that which appears clearly on the barograph-curves of tropical stations. The others, which we could obtain only by harmonic analysis of long series of observations, are the small stationary 12-hourly wave (predominant in polar regions), the 8-hourly wave with its contrast between the winter and summer hemisphere, and finally the lunar wave.

The lunar wave is most easily explained, because it has exactly the expected form of the tide produced by the Moon's gravitation. With the same certainty we can say that the 8-hourly wave is not gravitational in origin, because there is no such part in the tidal forces. In fact, it is produced by the 8-hourly wave of temperature, as was suggested by the fact that the 8-hourly waves in pressure and temperature show the same characteristic reversal from summer to winter.

The main solar 12-hourly wave of pressure is complex in nature. It consists of a gravitational part (with maxima about noon and midnight) and a thermal part (with maxima about 8 o'clock) produced by the 12-hourly wave in temperature; the combination of both gives maxima at about 10 o'clock as observed. And the zonal oscillation seems to be connected with the differences of the 12-hourly temperature-waves over land or sea.

These considerations are, however, only qualitatively satisfactory, but seem to fail quantitatively. Because, if the world-wide 8-hourly wave of pressure is produced by the small 8-hourly wave in

temperature, why do we not find a large world-wide 24-hourly pressure-wave caused by the large 24-hourly wave of temperature?

The answer may be illustrated by an electrical analogy which is nowadays perhaps more familiar to us than any mechanical analogy, namely, radio reception. For simplicity we consider a simple detector-set without amplifying tubes. Out of the great many electromagnetic oscillatory forces which are sent out by wireless stations and act incessantly on the antenna of this radio receiving set, all are suppressed except those of the period or frequency for which the set happens to be tuned, or, to use another expression, the set responds only to waves which are in resonance with the free oscillation of the set. The atmosphere, as a spherical shell, can perform a great variety of mechanical oscillations, but theory shows that only the kinds of oscillations shown in Fig. 25 are in tune with thermal or gravitational causes. All others, for instance, all the 24-hourly waves are more or less suppressed because of lack of resonance.

The detailed mathematical theory is intricate. Fortunately, for the case of an ocean of uniform depth covering the whole Earth, the tidal oscillations have been discussed by Laplace and Hough. Their formulae did not find any application whatever in that field for which they were derived, namely, in the discussion of the tides in the oceans themselves, because they do not consider the influence of the continents. But it has been possible to transfer their equations to the unlimited air-ocean, and the atmosphere is found to respond to tidal forces like a water-ocean of 5 miles depth.

The solar and lunar semi-diurnal pressure-wave (at the left and right in Fig. 25) have the same form of oscillation, but the lunar wave has a somewhat longer period, or, to use a radio expression, a lower frequenecy. The frequency per year of the solar semi-diurnal wave is, of course, $2 \times 365 = 730$, that is, the peak of the solar semi-diurnal wave passes each station 730 times per year. The frequency of the lunar semi-diurnal wave is only 705 cycles per year. The free oscillation of the atmosphere seems to be about four minutes less than 12 hours, corresponding to a frequency of 734 cycles per year. Now if we have a receiving set tuned to the frequency 734 cycles, and two stations are sending, *S* on the near frequency 730 and *M* on frequency 705, it is clear that station *S* is received with much higher intensity than station *M*, even though *M* may send out higher energy. The application to the oscillations of the atmosphere is evident, though the analogy has of course its limits.

This so-called resonance-theory was first suggested by Lord Kelvin and has been developed by Rayleigh and Margules. Though many difficulties remain, confidence in this theory has recently been strengthened. The theory predicts that an atmosphere that is nearly perfectly tuned in on the progressive solar 12-hourly wave must be also tuned in on the zonal 12-hourly wave and on the 8-hourly wave, and that is exactly what we have found in the observations.

It seems to be more or less fortuitous that the Earth's atmosphere is just so well tuned. If the Earth would lose 10 per cent. of its air, the atmosphere would be tuned in on the lunar semi-diurnal wave, and if it would lose about 30 per cent.—so that the air-pressure at Washington would decrease to the amount which we now observe at an altitude of 10,000 feet above sea-level—none of the world-wide oscillations would be observed at all.

Our survey of the atmospheric tides would not be complete without a brief comparison with similar phenomena. Tidal forces reach enormous amounts when two celestial bodies pass each other

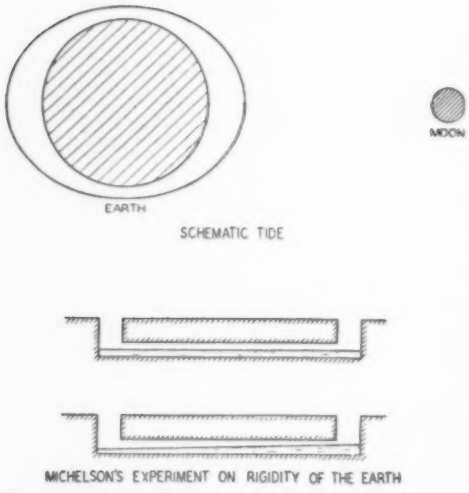


FIG. 26. SCHEMATIC TIDE AND MICHELSON'S EXPERIMENT ON RIGIDITY OF THE EARTH.

at short distance, and the birth of our planet-system has been ascribed to such an encounter of our Sun with another star during which our Sun was not hit by the other star, but broken up under the stress of the gigantic tidal forces. Under present conditions, tidal forces are small on the Earth.

A beautiful experiment of the late Dr. A. A. Michelson has demonstrated the tidal forces and their effect on the solid Earth (Fig. 26). Under the influence of the Moon's tidal forces, an ocean that covered the Earth completely would tend to take the shape illustrated at the top of the figure. Michelson buried underground pipes 500 feet long and filled them half with water. The level of this water would oscillate just as the level of an ocean. Because of the short free oscillation-period of some minutes in such a short pipe the level would adjust itself perfectly to the tidal forces and it is possible to calculate theoretical level-changes from astronomical data. Michelson measured these slight level-changes at the end of the pipe by an ingenious device and compared his observed changes with the theoretical values in order to find whether the solid Earth is perfectly rigid, or whether it is elastic. Because, if the solid Earth itself would yield perfectly to the tidal stresses, then the ground-surface would oscillate just as much as the water, and the observations would give no relative movement of water and ground at all; on the other hand, if the solid Earth were perfectly rigid, the observations would give the full theoretical value. Actually, the observed movements were seven tenths of the theoretical figures, so that the solid Earth yields only to three tenths to the tidal forces. Fig. 27 shows the tidal rise and fall of the water at the south end of a pipe stretching from north to south, for the interval from March 24 to April 21, 1917; the calculated values, which are seven tenths of the theoretical values, agree very well with the observed values. At new Moon, when Sun and Moon are in line, and at full Moon, when Sun and Moon are on opposite sides of the Earth, both pull together and produce maxima exactly at midnight and at noon; at the first and last quarter, Sun and Moon partly neutralize their influence, and the tides are small. The Moon has the greater force; therefore, the maxima occur every day about 50 minutes later.

This famous experiment not only shows the regularity of the tidal forces, but also the astonishing uniformity with which the solid Earth yields partly to the tidal stresses. No selective resonance of any kind disturbs the relation between solar and lunar tides in the solid Earth; both produce effects in the ratio of their forces. In further contrast to the atmospheric tides, no irregular effects are superposed on the minute tidal movements of the solid Earth so that instrumental precision can detect them hour by hour.

This yielding of the solid Earth has also a bearing on the theory of the atmospheric tides, because it demonstrates that the under-surface of the atmosphere

is itself in perpetual tidal motion. This is, of course, even more true of the oceans. But the coast-lines hinder the development of a great oceanic tidal wave traveling from east to west around the globe, and the tidal movements of the sea-water are resolved into a number of more or less independent oscillations of the single oceans and smaller gulfs and bays, governed in each individual case by resonance-effects. Nothing demonstrates the complicated nature of the oceanic tides better than the great differences on both ends of the Panama Canal, only about 30 miles apart: On the Pacific side, high and low water are 12 to 16 feet apart, while on the Atlantic side the rise and fall is less than one foot. It is a remarkable demonstration of the good resonance-properties of the atmosphere as a whole that the lunar atmospheric tides are so little affected by the erratic tidal movements of the surface of the oceans.

In comparison with these other tidal phenomena of the solid Earth and the oceans, the tidal oscillations of the atmosphere appear now in some ways more complicated, because they are influenced by the tidal movements of the surface of the continents and oceans, because, furthermore, temperature-variations and perhaps some other meteorological factors act in a similar way as gravitational forces, and because finally the atmospheric tides are hidden by large non-periodic variations; on the other hand, they are more simple because the resonance-properties of the atmosphere as a whole enhance the world-wide oscillations and repress local irregularities. Fig. 28 summarizes the essential features in three schematic spectra. The first shows the gravitational and thermal causes (expressed in equilibrium-values, that is, in terms of theoretical pressure-waves, if the forced periods were much longer than the free periods); the influence of the selective resonance of the atmosphere (shown in the second spectrum) multiplies certain of these causes by high resonance-factors, and suppresses others, which results in the observed oscillations (third spectrum).

It is a fascinating task to disentangle the delicate tidal oscillations of the at-

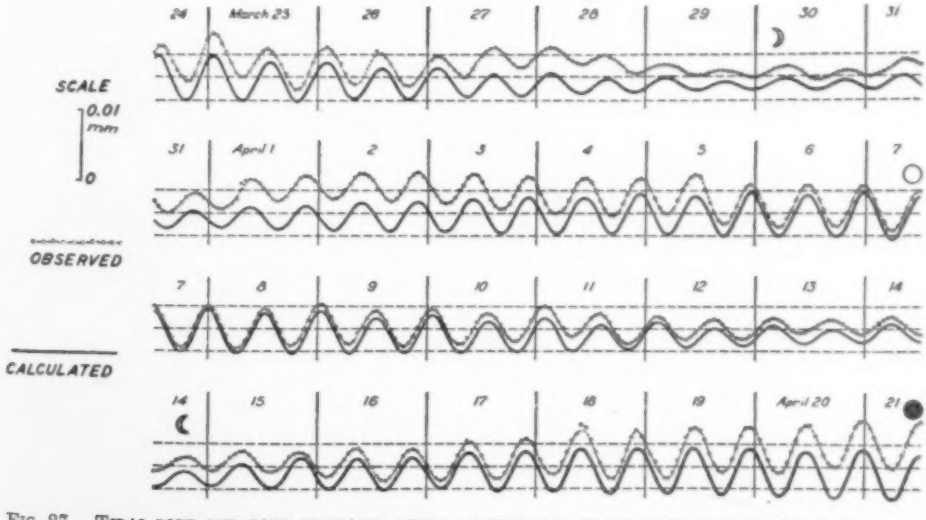


FIG. 27. TIDAL RISE AND FALL OF WATER-LEVEL AT THE END OF UNDERGROUND NORTH-SOUTH PIPE 502 FEET LONG AT YERKES OBSERVATORY (AFTER MICHELSON AND GALE) AS COMPARED WITH COMPUTED VALUES, MARCH 24–APRIL 21, 1917.

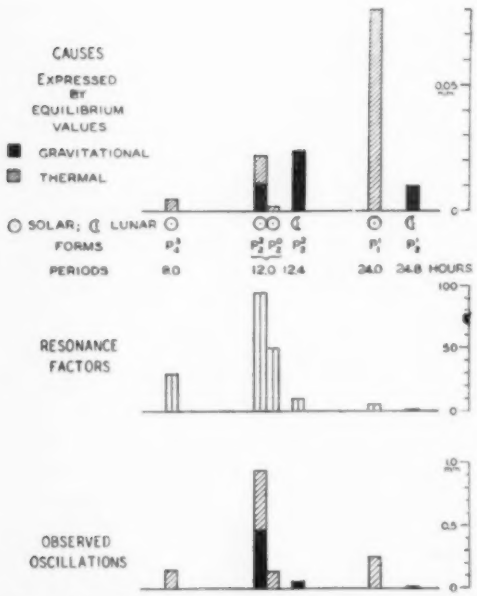


FIG. 28. SCHEMATIC SPECTRUM FOR WORLD-WIDE OSCILLATIONS OF THE ATMOSPHERE.

mosphere from the bewildering irregularities of the daily weather changes. For the weather-forecaster it might appear as a side-track, not worth while pursuing, but do not let us deceive ourselves by apparently practical considerations; those who study these minute phenomena as manifested in the pressure-waves near the ground, or in the magnetic variations as messages from great altitudes, have a similar aim to the physician who is not content to observe the more or less erratic behavior of a man but finds out more about his physical constitution by listening to the beat of his pulse.

Some papers bearing on tides in the atmosphere are:

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THIS YEAR'S ECLIPSE OF THE SUN

By JAMES STOKLEY

ASSOCIATE DIRECTOR, THE FRANKLIN INSTITUTE MUSEUM

WHEN the moon, in the course of its monthly circuits around the earth, passes between that body and the sun, producing a total solar eclipse, astronomers are always interested. And when the moon's shadow crosses a land area where there is a good chance of clear weather at the crucial moment, they do not hesitate to travel long distances in order to make the observations possible only at eclipse time. Thus, in October, 1930, two scientific groups, one from the U. S. Naval Observatory, the other from New Zealand, established themselves at Niuafoou, a nearly inaccessible little island in the Tonga group in the South Pacific Ocean. But total eclipses of the sun are not always visible only from remote parts of the world. In 1918 one was visible in the western United States, and many important observations were made. The year 1923 brought one to Southern California in September, but unfortunately the typically fine California weather failed to prevail. Few observations were made there, though astronomical parties in Mexico did have excellent conditions. When another eclipse track passed over New York, Connecticut, Rhode Island and Massachusetts early on the morning of January 24, 1925, the unexpected again happened, and the weather, along the eastern part of the track, was beautifully clear. An eclipse was visible along a path crossing England and the Scandinavian peninsula in June, 1927. Again, cloudy weather occurred over most of the track, but there were two notable exceptions. A German party in Lapland was favored with clear sky. In England, at Giggleswick, the point selected by the Astronomer Royal for the expedition of the British Royal Observatory, the day was almost completely cloudy, but a hole appeared in the clouds, surrounding the sun, just before totality. A few minutes afterwards it was raining.

With such interest shown in eclipses, it is not surprising that this year's eclipse, on Wednesday, August 31, has been eagerly awaited by astronomers, and by the general public as well, for many months. For the scientific fraternity, there is the added attraction in the United States of the meeting of the International Astronomical Union at Harvard immediately afterwards. This meeting would have been held last year, but was postponed to make it possible for foreign astronomers to combine it with the eclipse.

On August 31, according to the data published at the U. S. Naval Observatory by the Nautical Almanac Office, of which Professor James Robertson is in charge, the moon's tapering shadow first touches earth at 2:04.2 P. M., Eastern Standard Time (or 19h 4.2m G. C. T.) at a point in longitude 109° 16′ east of Greenwich and latitude 79° 36′ north. This is in the Arctic Ocean north of the East Taimir Peninsula. Thence the shadow travels northeastward and passes within a few hundred miles of the North Pole. As it then travels to the southeast, at an average speed of about two thousand miles an hour, it sweeps over Melville Sound, Prince of Wales Island, Boothia Peninsula, the District of Keewatin of the Canadian Northwest Territory, Hudson Bay, James Bay, the Province of Quebec and New England. Then it passes to sea and leaves the earth at 4:02.6 P. M., Eastern Standard Time (21h 2.6m G. C. T.) from a point in the

middle of the Atlantic Ocean with the coordinates of 40° 59′ west and 28° 27′ north, where the sun is then setting.

The path of the shadow in southern Quebec and New England is shown in detail in the accompanying map. Fig. 2 shows the shape of the shadow as it passes over this part of the earth. It is about 60 miles wide and a hundred miles long. In the middle of the eclipse track, where the widest part of the shadow crosses, the total eclipse will last about a hundred seconds. The lines crossing the shadow in Fig. 2, parallel to the edges of the path, are at ten-mile intervals and the numbers below indicate the time in seconds which that part of the shadow requires to pass a given point.

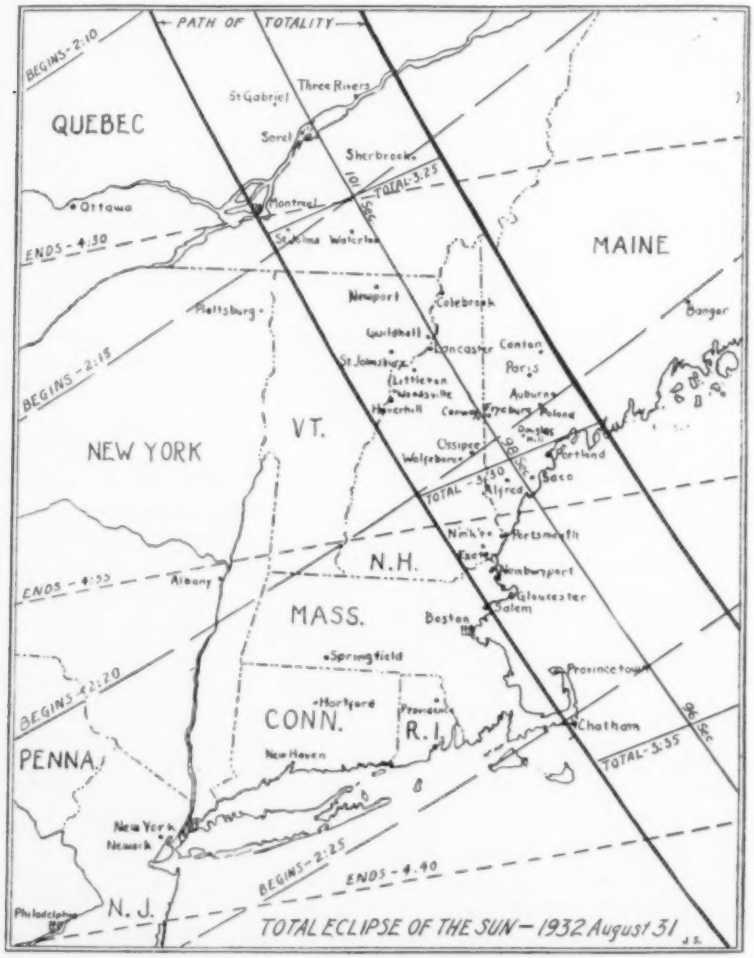

FIG. 1. PATH OF THE TOTAL ECLIPSE ON AUGUST 31, 1932.

THE ECLIPSE WILL BE SEEN AS TOTAL FROM POINTS WITHIN THE TWO HEAVY PARALLEL LINES, AND WILL LAST LONGEST ON THE CENTER LINE. THE NUMBERS ON THE CENTER LINE SHOW THE DURATION OF TOTALITY AT THAT POINT AND THE SOLID LINES CROSSING THE PATH SHOW THE TIME OF MID-TOTALITY. THE LONG LINES CROSSING THE ENTIRE MAP SHOW THE TIMES OF BEGINNING AND ENDING OF THE PARTIAL PHASES. TRACED FROM A MAP ISSUED BY THE U. S. NAUTICAL ALMANAC OFFICE.

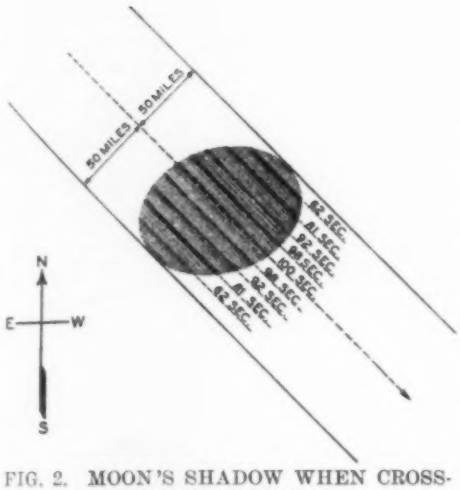

FIG. 2. MOON'S SHADOW WHEN CROSSING NEW ENGLAND.

REPRODUCED FROM A PAMPHLET ISSUED BY THE NEW ENGLAND HOTEL ASSOCIATION.

It will be seen that, while longest duration is at the center, the total eclipse will last at least a minute over a band 80 miles wide.

To an observer in the path of totality, the first warning of the coming event will occur at about 2:20 P. M., Eastern Standard Time, for a point in New Hampshire or Maine. At that time, if the observer looks at the sun, with proper protection, he will see a slight nick in the right-hand edge. The best way to look at the sun is by means of a small telescope, but of course one should never look directly at it. If the telescope is set on a firm support, and pointed to the sun, a piece of white cardboard can be held a few inches from the eyepiece in such a way that a good image of the sun is obtained. Focus can be secured by adjusting the telescope eyepiece, or by altering the distance of the card. It is usually necessary to place another card, with a small hole in the center, around the telescope like a collar, in order to shield the screen from the direct rays of the sun. The sun can be viewed directly by the time-honored smoked glass, but better yet is a dense photographic negative.

The nick which appears in the right-hand edge of the sun at about 2:20 is the moon, which is now starting to come between the sun and the earth. Gradually the nick increases in size, as more and more of the solar disc is covered. Finally, the remaining part of the sun assumes the shape of a crescent, which continues to narrow. The sun's light assumes a peculiar yellowish color, because the bluish rays from the inner solar disc, ordinarily present in sunlight, are now eliminated. The spots of light under foliage, consisting of solar images made by the pinholes formed by the interstices between the leaves, are crescent shaped, instead of round. Perhaps the shadow bands may appear. These are waves of light and shade which pass across light objects, like the white-washed side of a house, facing the sun. They are caused by streaks of varying density in the earth's atmosphere, and were very conspicuous in 1925 on the snow-covered ground. At some other eclipses they have hardly appeared at all.

Totality arrives, in New England, at about 3:30 P. M., as indicated on the map. If the observer has a clear view to some distance in the northwest, the moon's shadow can be seen approaching, like a tremendous storm-cloud, with awe-inspiring swiftness. At the same time, the last-vanishing sliver of the sun's crescent breaks up into a series of bright spots—the Baily's beads, caused by the sunlight shining through valleys on the limb of the moon, while adjacent lunar peaks already have passed the edge of the solar disc. The beads last only a moment, then, completely encircling the dark disc of the moon, now visible in its entirety, there flashes into view the magnificent corona of the sun, shining with a pale greenish light about half as brilliant as the full moon. The shape of the corona varies in step with the number of sunspots. As they are now at a minimum, the corona should probably

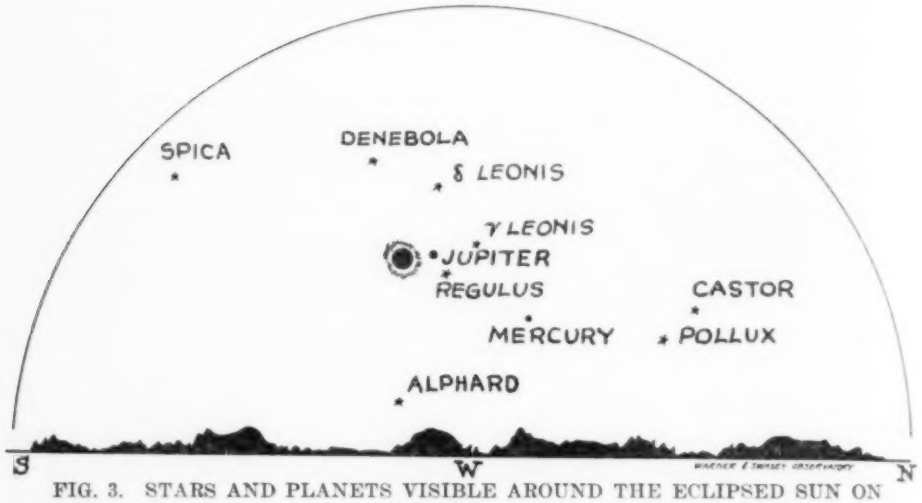

FIG. 3. STARS AND PLANETS VISIBLE AROUND THE ECLIPSED SUN ON AUGUST 31.

FROM A DRAWING PREPARED BY DR. J. J. NASSAU, OF THE WARNER AND SWASEY OBSERVATORY OF THE CASE SCHOOL OF APPLIED SCIENCE.

have several long streamers, extending out from above the sun's equator to perhaps several times its diameter. From the poles there may emerge a series of brush-like rays of light. Close to the moon's disc there may be seen some of the red solar prominences, huge flames of hydrogen and other gases. Glancing around the sky, some of the brighter stars and planets can be seen. Jupiter shines brilliantly just to the right of the sun, and Regulus is just below. Still farther to the right is Mercury. These objects, and a few others, as they will appear at the time of the eclipse, are shown in Fig. 3, in a drawing prepared by Dr. J. J. Nassau, of the Warner and Swasey Observatory, Cleveland.

But not for long can one enjoy this spectacle of the total eclipse. About a minute and forty seconds after the corona made its appearance, its outer extensions begin to fade away, and the Baily's beads reappear, this time on the right-hand edge of the sun. The shadow is seen receding rapidly to the southeast. The Baily's beads coalesce to form a thin crescent of sunlight. Possibly, to a keen eye, the inner part of the corona may hang on for a moment or two after the sun has begun to emerge from the eclipse. The first reappearing bit of the sun, made larger by irradiation in the eyes, which have become dark-adapted during the eclipse, looks much larger than it is. Coupled with the continuous circle of the inner corona, the appearance is that of a diamond ring, the name coined for the effect when it was noticed by millions in 1925. Then the crescent of sunlight grows larger, as the moon moves off the solar disc to the left. Finally, at 4:34 P. M., the last nick on the sun's limb vanishes, and the eclipse of August 31, 1932, is over.

Not until 1963 will American astronomers again have the chance to observe a total eclipse with any probability of success. The next total eclipses of the sun visible at all in the United States are scheduled for July 9, 1945, and June 30, 1954, but these both begin in the northwest at sunrise and pass over into Canada a few minutes later. On July 20, 1963, there will be an eclipse which almost duplicates the one of this year. It is visible over practically the same path, and lasts almost exactly the

same time. Relying too implicitly on the approximate charts published in Oppolzer's famous "Canon der Finsternisse" (Vienna, 1887), astronomers have not generally realized that this eclipse would be visible in the United States. Like the one of this August, it is shown in Oppolzer's maps as passing through Nova Scotia, completely missing the United States. In his introduction, as Dr. A. C. D. Crommelin has pointed out (*Observatory*, Vol. liii, p. 310), Oppolzer specifically states that the charts are merely approximate, as he has located the two ends and the middle of each track, and connected them with circular arcs, a figure quite different from the eclipse tracks. The data given in the tables in the same work show a track for this year's eclipse corresponding within a mile to that computed by the Nautical Almanac Office. Crommelin makes a plea, which the present writer seconds, that when speaking of the "path given in Oppolzer," astronomers should refer to the path computed from his data, and not that in the charts, unless specially designated. The true Oppolzer paths, for eclipses of the present century, are given by Mähler in the *Denkschriften of the Vienna Academy*, Vol. 49.

After 1963, the next favorable American eclipse will be on March 7, 1970, in Florida. This will be followed by one on February 26, 1979, in the northwestern states along a line parallel to the Canadian border. Two others will come in 2017 and 2022, the latter passing close to New York City. The next eclipse of interest to astronomers, in any part of the world after this year, will be in 1934, when one will be seen from the South Pacific Ocean on February 14. Another will be seen from Japan in 1936, on June 19, and a very long one, lasting seven minutes, from another part of the South Pacific Ocean on June 8, 1937.

It is doubtful, however, if any eclipse, for many years to come, will be seen by as many astronomers and lay observers as the one this year, assuming that favorable weather conditions permit it to be seen all along the track. A preliminary list of the expeditions, prepared by Dr. Frederick Slocum, chairman of the American Astronomical Society's eclipse committee, supplemented by several others known to the writer, shows twenty institutions represented, at nine separate points along the path of totality. The location selected by three of the groups is unknown at the time of writing. Also, several other institutions, that frequently observe eclipses, have not yet announced their plans, and it is certain that a number of other parties will be present.

Northernmost of the stations will be Parent, P. Q., a small town on the Canadian National R. R. The Royal Observatory at Greenwich, under Dr. John Jackson, chief assistant, and the Dominion Observatory at Ottawa, under Professor R. Meldrum Stewart, the director, will combine forces at Parent. Montreal, though it is near the edge of the path, has the advantage of a permanently established observatory at McGill University, and this will be used by Professor A. S. Eve, of that institution, and also by Professor A. Fowler, from the University of London. At Magog, P. Q., the party from Cambridge University, under Dr. F. J. M. Stratton, will be joined by Dr. S. A. Mitchell's group, from the McCormick Observatory of the University of Virginia. Professor C. A. Chant will head the University of Toronto's expedition, at St. Alexis, P. Q.

Coming into the United States, the Sproul Observatory of Swarthmore College will erect its equipment, including the 65-foot eclipse camera, at a point in northern Vermont. At Lancaster, N. H., will be the Mt. Wilson Observatory astronomers, under the direction of Dr. Walter S. Adams. A group represent-

ing The Franklin Institute, Philadelphia, under the writer's direction, will be located at Conway, N. H., with a coelostat camera of 85 feet focal length, as well as smaller instruments. Dr. Frederick Slocum, of the Van Vleck Observatory, Wesleyan University, has chosen Center Conway. Across the state line, at Fryeburg, Maine, will be a concentration of several parties. These will include groups from the Lick Observatory, under Professor J. H. Moore; Georgetown University, under Rev. Paul A. McNally, S.J.; the University of Michigan Observatory, under Professor H. D. Curtis; and the Dearborn Observatory of Northwestern University, under Professor Oliver J. Lee. The Perkins Observatory of Ohio Wesleyan University, under Dr. Harlan T. Stetson, its director, and the Warner and Swasey Observatory of the Case School of Applied Science, under its director, Dr. J. J. Nassau, will combine forces at Douglas Hill, Maine. At Biddeford, Maine, will be the group from the Deering Observatory, headed by Mr. Frank Deering. In addition, the Kwasan Observatory of the Kyoto Imperial University, Japan, and the Russian National Observatory, at Poulkovo, have announced plans to send expeditions, the former in charge of Professor Issei Yamamoto, and the latter of Professor A. Belopolsky.

Practically all these parties will make direct photographs of the corona, and a few, like the party of The Franklin Institute, will specialize in this field. Besides the photographs with the long focus cameras, smaller instruments will be employed, some to make a motion picture record, others, for special purposes, such as photographs in natural colors. Attempts will be made to photograph the moon's shadow from an airplane. If the edge of the shadow can be photographed on the ground, together with recognizable landmarks whose position can be accurately determined, a very precise determination can be made of the relative positions in space of the earth, moon and sun. Still other photographs will be made of the partial phases, and possibly of the shadow bands, if they appear.

At least two prominent artists will paint the eclipse in oil, a method that has been found to give a more accurate record of how an eclipse really looks than any of the photographic processes. At York Harbor, Me., Mr. Howard Russell Butler will make a painting from his own summer home. Mr. Butler has painted the last three eclipses seen in the United States, but to do so he has had to travel to Oregon in 1918, to California in 1923, and to Connecticut in 1925. The paintings are now hanging in the American Museum of Natural History, in New York. But now the mountain actually comes to Mohammed! Mr. Charles Bittinger, of Washington, D. C., and Duxbury, Mass., is also known as a painter of scientific subjects, and has already done the solar spectrum and the zodiacal light. He will paint the eclipse as a member of the party to Conway from the Franklin Institute.

Perhaps the most important eclipse observations, however, are those made with the aid of the spectroscope, particularly of the so-called "flash" spectrum, an observation that forms the specialty of Dr. H. D. Curtis and of Dr. S. A. Mitchell. Just as the last shred of the solar disc appears at the beginning of totality, and just as it first reappears at the end, the sun's atmosphere shines unmixed with light from the inner region. Its spectrum is a series of bright lines, unlike the dark line spectrum of ordinary sunlight, and photographs of this spectrum yield much important information about the sun's constitution. Other spectrum photographs, made during totality, reveal the make-up of the corona. Photo-

graphs made with the interferometer tell how the material in the corona is moving.

Despite the question raised recently by Professor Erwin Freundlich, of the Einstein Tower at Potsdam, regarding the validity of determinations of the Einstein shift of starlight passing close to the sun, as measured on eclipse photographs by Eddington, Campbell, Trumpler, Chant and others, it is not expected that any plates to confirm this effect will be made this year. The sun is in a poor field, with no bright stars nearby. Professor James Robertson, the director of the Nautical Almanac, has called attention to the good star field that will surround the February 14, 1934, eclipse, so probably that will be used for the purpose.

Away from the path of totality, of course, the effects of the total phase will be missing, but the partial eclipse will be interesting to watch. This will be visible over the entire continent of North America. The closer one is to the total eclipse track, the larger the partial eclipse will be, but as far away as southern California the moon will cover nearly a third of the sun's diameter when the eclipse is at its maximum. Even at this distance, the crescent-shaped spots of light will be noticed under trees. At points as close as Denver, Colorado; Helena, Montana, or Juneau, Alaska, the eclipse will be about fifty per cent. total. Atlanta, Georgia, will get 73 per cent., Chicago, 79 per cent., and Richmond, Virginia, 87 per cent. Philadelphia will get 93 per cent., New York 95 per cent. and Boston 99 per cent. In places as close as the last three, the peculiar yellowish color of the sunlight may be noticed, and it is possible that, where the eclipse is as much as 95 per cent. total, the shadow bands may be seen. In 1925 they were noticed at places a considerable distance from the path of totality. Also in these places, as at locations within the path, the chickens and other birds may be observed going to roost, as the darkness increases.

To the amateur astronomer, or photographer, the eclipse offers an unusual opportunity, especially if he be in the path of totality. While he can not hope to equal the work of the large cameras of the scientific parties, the amateur with a hand camera can make a very interesting record of this striking event. With a lens of 10 inches focus, the sun's image is a little less than a tenth of an inch in diameter, and if the picture is sharp, it can be enlarged considerably with quite satisfactory results. If a longer focus lens is available, it should be used. With a lens of not more than twenty or thirty inches focal length, and an exposure of not more than five seconds, the sun's motion will not be appreciable, and there is no need to mount the camera to follow the earth's diurnal motion. If the lens has a relative aperture of approximately F. 8, an exposure of perhaps two seconds can be given, though it is almost impossible to give a wrong exposure for such pictures. The inner corona is so brilliant that even an exposure of a fraction of a second will record it, while one of longer duration will overexpose the region, but will record the outer corona. Another interesting camera record can be made by taking a series of pictures at regular intervals such as every five minutes, of the partial phases and of the corona, on the same plate. If one has a 16 mm motion picture camera, it would be of interest to use it also.

But whether or not one goes to make any observations, amateur or professional, it should be remembered that Wednesday, August 31, brings the chance of a lifetime to observe an impressive and beautiful natural phenomenon, and no one interested in such things should miss it if he can possibly avoid doing so.

MODERN PSYCHOLOGY AND THE LAW: A MAJOR PROBLEM OF SOCIAL SCIENCE

By Dr. PAUL C. SQUIRES

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THE public at large has never shown a more intense interest in things legal than at the present day. Popular attention is quite naturally concentrated on the more sensational and emotion stirring phases of the law. Much talk is to be heard on every hand about the activities and mind of the criminal. The press is flooded with accounts and discussions of crime. During the past year or so the movies have virtually been obsessed with the headline topic of the criminal, crime and punishment. In the midst of all this it would seem timely to make some remarks on certain fundamental matters involved in the relations between psychology and law.

The history of law is the story of man's slow and painful progress in the direction of a more effective regulation of society. The development of the law is a vast and ever-continuing enterprise, calling for the vigorous cooperation of many realms of knowledge. Psychology, from its very nature, must become inseparably linked with such progress. On the one hand, psychological research in the field of the law is bound to illuminate many of the obscure questions of psychology itself; on the other, such research is certain to find practical expression in the betterment of the law.

ATTITUDE OF THE LEGAL PROFESSION

It is almost a truism that the rank and file of the legal profession have not been responsive to the findings and suggestions of psychologists. Of course there can be no question that a cautious and conservative attitude is amply justified; for admittedly great difficulties are to be encountered at almost every stage of psychological analysis and prediction. Yet all too often, over and above the desirable attitude of conservatism, there is plainly manifest on the part of lawyers an impulsive, violent hostility toward the teachings and resources of modern psychology. The contributions from this province are quite obviously looked upon by the great majority of lawyers as unwarranted interference with what they jealously guard as an exclusive preserve, not to be "trespassed" upon under any circumstances.

Needless to say, this hostility offers a most serious obstacle to the closer and much-needed alliance between law and psychology. That the antagonistic feeling has frequently been unduly heightened by the too hasty approach of enthusiastic psychologists to a very complex and preeminently practical problem can not be denied. Moreover, it is only rarely that psychologists have spent enough time and energy in obtaining an understanding of the actual machinery of the law and the point of view of a necessarily practical bench and bar.

The other side of the picture, however, is that lawyers as a class have not been at pains to acquaint themselves with the trends of present-day psychology. But only by so doing can they be in any position to pass competent opinion on the matter in issue. Lawyers are quick to raise the facile criticism that psychology is not a science. What if psychology is not a science? Whether it is more art than science is, as the lawyers are so fond of saying about other moot points, a "purely academic question." The only relevant

question presenting itself in this connection is whether modern psychology offers the best ground from which to attack the mental problems inevitably tied up with legal situations.

The Rise of a Legal Psychology

Originating largely in the pioneer experiments on testimony conducted by Hugo Münsterberg, of Harvard, a legal psychology has gradually been taking form. But legal psychology is a highly specialized field. Because of the great difficulties encountered in applying psychological methods and principles to the rough-and-tumble conditions of everyday law practice, it would seem essential that investigations in legal psychology be carried out whenever possible by psychologists possessed of a good legal background. The cloistered atmosphere of the academic laboratory is far removed from the emotion-charged air of the legal battle front.

The keynote of the age is cooperative research. And it is noteworthy that in the Psychological Corporation of New York City we have available a widespread organization devoted to the solution of practical problems in what has aptly been called human engineering. The corporation is interested in all problems of applied psychology, among which looms large this very intricate and socially urgent one of legal psychology.

The Criminal

Our system of criminal law rests upon an ancient foundation whose cornerstone bears the inscription "Free Will." However, the legal tests used for determining the degree of responsibility of the offender have slowly undergone the civilizing process. The "wild-beast" test, put forward in 1732 by Mr. Justice Tracy at the trial of Arnold for the attempted murder of Lord Onslow, laid down the stringent requirement that the defendant, in order to escape punishment, must be totally deprived of his memory and understanding. In 1800 this test was replaced by that of ability to distinguish between right and wrong in the abstract; the occasion of this change was the trial of Hadfield, who had made an attempt on the life of the king in Drury Lane Theater. Then came the epoch-making McNaughton trial of 1843. Daniel McNaughton, suffering from insane delusions of persecution, planned to murder Sir Robert Peel, but through mistake killed Drummond, secretary to the prime minister. The acquittal of McNaughton precipitated such wide popular dissatisfaction that the whole matter was debated in the House of Lords. The final outcome was the formulation of the now famous McNaughton Rules. These require that the defendant, in order to merit punishment, must be able to distinguish between right and wrong in respect to the particular act for the commission of which he is tried. Through these rules was accorded by the English courts the first formal recognition to what is known as "partial" insanity. The rules were also crucial in hastening the coming of the doctrine of individualization in the provinces of criminology and penology.

Mr. Chief Justice Cardozo, of the New York Court of Appeals, writing the opinion in the Schmidt murder case of 1915, has well said: "We must not, however, exaggerate the rigor of the rule by giving the word "wrong" a strained interpretation, at war with its broad and primary meaning, and least of all, if in so doing we rob the rule of all relation to the mental health and true capacity of the criminal" (216 N. Y. 324, 339). And yet, surprising as it may seem, it was not until 1919 that the New York Legislature recognized mental deficiency. The work of the mental examiners has progressed tardily in the courts, although there are signs to be

noted here and there that courts are more willing than formerly to take into consideration psychological findings. In the rape case of People *v.* Palvino, which came before the Fourth Department of the New York Appellate Division in 1926, Judge Davis, writing the opinion for a unanimous court, said: "The evidence was strong not only that the female was a mental defective, as defined by section 2 of the Mental Deficiency Law, but was mentally of the age of but seven years and two months, as determined by tests recognized by scientists and applied in this State by officials to whom is given charge of such unfortunates" (216 App. Div. 319, 321). Although there is no available space to discuss the many difficulties presented to the professional psychologist by the concept of mental age as expressed in terms of years and months, it is nevertheless certain that the above decision is most noteworthy and encouraging as an indication of the changing attitude on the part of the courts toward the findings of modern psychology.

It is much to be hoped that the time will arrive when states will establish regional boards of jurists, psychiatrists and psychologists, upon whom will devolve the arduous task of mapping out individualized treatment for those who have broken the rules of society. The monumental work of Dr. William Healy on the Judge Baker Foundation demonstrates the correct approach to the problems of crime through the study of the individual delinquent. Dr. Healy and his associates have brought to bear upon their undertaking the most approved techniques of modern psychology. The tremendous impetus given by the brilliant series of scientific investigations conducted by Dr. Healy to a more adequate comprehension of the criminal mind is now a matter of history. These researches, dealing with the psychology of the adolescent delinquent, are devoted to fundamental questions of social prophylaxis. There can be no doubt that a significant proportion of criminal careers could be prevented by the application of a carefully organized psychological service in connection with the routine of our juvenile courts; some of the courts are doing so, but their number as yet is relatively small, although growing. In order to accomplish this end more effectively the upper age limit for the juvenile court should be raised to eighteen years—sixteen is decidedly too low. The general public is well aware of the scathing denunciation launched by a recent report of the Wickersham Law Enforcement Commission against the Federal system of handling the child offender. As concerns an effective parole and probation system, there are urgently needed the extensive services of clinical psychologists for the purpose of predicting the probable boundaries within which the delinquent can be trusted out in society.

Law as a Social Science

Time was when logical perfection was the chief ideal of the doctors of the law. But for some generations there has been taking place a shift away from the hair-splittings of a medieval formalism toward the recognition of law as a psycho-social problem. The psychological attitude is irresistibly taking hold of society as a whole. This is the era of science and social realism. Psychology conceals within itself no threat of disrupting the historical continuity of our legal system, but gives splendid promise of hastening the work of confirming what is wise in the law as it now stands and rejecting what is unsound. A true science of law, and of judicial proof in particular, can be attained only by realizing the extent of the contributions and the possibilities of a psychology whose point of view, methods and techniques are steadily converging upon social welfare as the goal. No science, be it of law or anything else, can arise upon mere rule of thumb.

To pick out just one of the many problems of the criminal law: the indeterminate sentence has latent within it immense potentialities for social progress. But the successful operation of this type of sentence requires far more than a stereotyped course of procedure. It is the individual offender who is sentenced and is undergoing sentence; the indeterminate sentence can have only indifferent worth if it be not carefully adjusted to his special mental organization. The psychological approach is indispensable here.

Psychology and the Law Schools

A thorough grounding in the best that psychology has to confer should be made an essential and required part of legal education. Specially designed courses in psychology should be instituted, whose function it would be to focus psychology upon practical problems of the law. The ultimate difficulties confronting the lawyer are not as a rule those pertaining to questions of law as such—although these are complicated enough in themselves; the crucial problem is usually presented by the devious ways of human nature. There is, to be sure, no real substitute for practical experience in any profession; but every effort should be made by those in charge of professional training to insure the best possible preparation. The young law school graduate, knowing so little about the mechanisms of human behavior, goes forth to cope with situations involving at every turn men's motives and actions. Legal tradition has strongly tended to fill him with the comfortable belief that the fund of learning culled from case books and statutes is quite sufficient unto itself. But he is not long in discovering, to his dismay, that the actual state of affairs resolves itself not only into so many legal factors, but also into completely undreamed-of psychological puzzles which he is untrained to solve. Medical schools are realizing the great danger arising from sending their students out into the world without some introduction to modern psychology. In like manner, schools of law will come to realize that the training of the lawyer does not begin and end with the study of merely legal facts and principles, but that the young student of the law, so strikingly naïve in the ways of mind, should be instructed in matters psychological early during the course, and that this instruction should be explicit and systematic.

The Outlook

The law, confronted as it is to-day by baffling problems of human adjustment set by a social environment ever growing in complexity, stands in need of all the help it can get through cooperation with modern psychology. In the administration of the law it must be presumed that the humanistic point of view is controlling. And a sound humanism is founded upon the willingness to accept all the aids that the world of knowledge can offer, wherever found. The weighty duty of distributing justice to the members of society presents an unsurpassed challenge that unreservedly calls for the breaking down of the lofty barriers of false pride and prejudice erected of old between the law and a psychology that is ceaselessly striving to become scientific. There is now taking place in the law a revaluation of values. Yet the memorable words of the philosopher Nietzsche are even to-day not without significance for the law: "Because it is old, however, and smelleth musty, therefore is it the more honored. Even mould ennobleth."

The law, if it would attain the rank of a genuine social science, must come to enter into a mutual benefit association with psychology. Indications are not lacking that the hope of such an alliance will some day become a reality.

THE VERDICT OF PSYCHOLOGISTS ON WAR INSTINCTS

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In consideration of the social significance of the traditional doctrine concerning man's war-making instinct, it seemed highly desirable to seek what might be taken to represent a sort of official expression of opinion by psychologists regarding it. The rights of psychologists as well as the interests of society might be considered to be involved, since they, presumably, are, in their particular field of scientific inquiry, primarily concerned with laws governing human behavior. Accordingly the writer addressed a question to the members of the American Psychological Association, the returns from which he is herewith submitting. The question was framed directly to fit the concept of the war instinct which was considered to be current in popular thought. There was no intention to draw inferences as to the attitude of psychologists respecting the possibility of ending war, or respecting any particular plan of doing so. The question is a specific one concerning a psychological doctrine, which has been made current by soldiers, law-makers, journalists, economists, historians, and all sorts of other makers of public opinion. The doctrine has been promulgated as though by warrant of psychology itself, and so far it has stood without authoritative challenge. To psychologists who are familiar with the recent changes of opinion concerning instincts in general, the disparity between current tradition and scientific opinion on this matter may seem obvious enough. But this disparity has not been pointed out with sufficient effectiveness to alter popular thinking. Hence this investigation.

The question sent to the membership of the American Psychological Association was stated as follows: Do you as a psychologist hold that there are present in human nature ineradicable, instinctive factors that make war between nations inevitable?

There are 528 members of the association. Of these 378, or 70 per cent., answered. The vote stands as follows: No, 346; yes, 10; unclassified, 22.

The question was not framed so as to elicit comment, but perhaps, through interest in the subject, or else by way of making their answers more complete, many respondents added valuable observations to their votes. Some wrote letters. These comments can scarcely in justice be left out of this report. They are, moreover, of much value by way of affording a cross-sectional view on a question which is of great social import, and at the same time of considerable scientific interest.

Of those who voted in the negative 71 gave emphasis to their answers by heavy underscoring, exclamation marks, repetitions, etc. Other negative voters indicated impatience at being called upon to vote on a question which to them seemed so obvious.

Still other negative voters added comments which are quoted as follows: "Man never loses his instinctive desires and trends, but within historical times he has evolved ethically to such a point that he controls them better than he did 4,000 years ago. The process will continue, and in the course of time there will be no wars."—*E. S. Abbot.* "Instincts can make for peace as well as war."—*L. Ackerson.* "There are elements that make one stand for one's rights, but there is a natural balance between them and the several socializing elements that lead even more strongly to mutual understanding and cooperation."—*C. H. Bean.* "The human

being has few or no ineradicable tendencies."—*J. V. Breitwieser.* "While I am a strong 'hereditarian' as regards fundamental tendencies in human nature, I do not see how any thinking person can believe in an 'instinct for war' or for the complex emotions which produce war."—*J. A. Charters.* "Absolutely no instinctive process of this or any other kind."—*H. W. Crane.* "Adequate universal education will show its (war's) medievalism and barbarism."—*G. V. N. Dearborn.* "There *may* be pugnacious instincts, but they certainly don't make war inevitable."—*H. B. English.* "No. Such a view is tommyrot, bosh."—*G. A. Feingold.* "No! Nothing that intelligence and education can not eradicate."—*H. H. Goddard.* "We may have a pugnacious instinct, but it can be controlled, as experience amply shows."—*S. J. Holmes.* "It (war) is social degeneration comparable to individual insanity."—*P. Hughes.* "No. What d.f. does?"—*H. M. Johnson.* "No. Don't be silly. Disputes between individuals may lead to war between nations, but what ever made any one think that it was an instinct?" In a subsequent letter the same respondent said, "I know that it is a favorite political device to say that the people's pugnacious instinct has been aroused and that war is, or was, inevitable. Such a statement is *silly,*—in the true sense of this word, since it does proceed from and is characterized by lack of wisdom."—*C. Landis.* "There are no instincts and nothing is ineradicable in course of evolution."—*W. M. Marston.* "Some strife between individuals we shall probably always have; but nations are artificial units, and wars between them can be kept up only by deliberate propaganda."—*M. F. Martin.* "Nonsense! Why blame the instincts for our stupidity?"—*H. Meltzer.* "The abolition of duels in Anglo-Saxon society is a striking and suggestive fact worth remembering."—*Adolf Meyer.* "Positively *not.* Any one who thinks so is densely ignorant of political affairs. Wars are artificial, commercial, strategic, political, trumped up and forced upon us."—*A. S. Otis.* "Primitive man fought over roots and berries; we over markets. Cooperation, founded upon (equally innate) sympathy and gregariousness, seems a possible solution—when leaders are sane."—*S. M. Ritter.* "No. I regard war as a social form of behavior."—*E. A. Shaw.* "No. As evidenced in the reduction of warfare between nations through international social, political, and economic progress."—*A. M. Snyder.* "No. I believe they (instinctive factors) can be disciplined and controlled by police power."—*D. Starch.* "It is conceivable that other methods of settling disagreements may yet be found,—methods more effective and socially more acceptable."—*E. T. Sullivan.* "War is due to something not original: the clash of 'opinions.'"—*J. W. Todd.* "Individuals engineer war and all other cooperative large scale operations of society."—*H. A. Toops.* "No, on the existence of a 'fighting instinct.' If there were, their manifestation or expression in war, I believe, would not be 'inevitable,' unless by *definition* an instinct and its specific form of expression are inseparable."—*M. C. Tufts.* "The instinctive tendencies are subject to training."—*J. H. White.* "No. No modern psychologist holds such a view."—*J. U. Yarborough.* "Not at all; only if one is guided by the baser elements of his native disposition."—*M. J. Zigler.*

Besides those who, as above shown, added reinforcements to their negative answers there are others who added reservations or modifications. These are quoted as follows: "Not if 'nations' give up some of their silly independence and manufactured nationalism. It is precisely the same problem as that of a class war. When it comes to racial expansion the problem is harder."—*H. A. Aikins.* "It seems reasonable to me to believe that a time will at length be reached in the course of human progress when these factors will be sufficiently controlled to lead to adjustment of differences with-

out resort to war."—*M. L. Ashley.* "Not much to judge on, but would like to say 'No.' "—*H. J. Baker.* "We could get rid of formal war, but there would still be criminal nations that need policing and punishment. The social problem of war is like the individual problem of crime."—*E. G. Boring.* "No. But of course I don't know whether I am right or not."—*D. R. Brimhall.* "The struggle for existence, for power, will always cause conflict in some form, but not necessarily war as we now understand it."—*K. Brousseau.* "No. I doubt whether instincts can be *uprooted* or should be."—*L. W. Cole.* "It seems that many of the factors underlying war are based on instinctive tendencies, but, since such tendencies are subject to control, the inevitableness of war is very doubtful."—*J. E. De Camp.* "Stated in terms of what is most probable, I would say there are probably no such factors."—*R. M. Elliott.* "No, though I think there are enough such factors to make its (war's) prevention very difficult."—*M. R. Fernald.* "Not inevitable but likely."—*S. Froeberg.* "No, if you mean by 'ineradicable' that the expression of instincts cannot be altered by training."—*J. P. Guilford.* "I would not 'eradicate' any unlearned tendency, but 'modify' or 'develop' it through experience, which is education."—*F. M. Hamilton.* "Instinctive tendencies but not ineradicable."—*S. B. Heckman.* "No; likely, but not inevitable."—*E. N. Henderson.* "War is natural relief to adverse economic conditions that result from crowding. A civilization that provides adequate sustenance automatically makes war unnecessary."—*J. P. Hylan.* "No. Though they, together with our forms of social and political organization, will make wars highly probable for the next few hundred years."—*H. D. Kitson.* "No, with reservations."—*C. L. Kjerstad.* "Not inevitable but more probable than a 50–50 change."—*F. B. Knight.* "No, but there are inherent needs and the competition for the means of satisfying these needs tends in a measure toward war."—*F. H. Lund.* "No, but they do make peace and friendly relations difficult. It is a long road to travel to international peace, but undoubtedly we are already far on the way."—*M. J. Mayo.* "No. I could amplify this position if you ask for factors (*e.g.*, conflicting self-interests) that are based upon more general drives, as hunger, self-satisfaction, etc."—*N. C. Meier.* "There may be such instinctive factors but I believe they can be sublimated into activities that will prevent war."—*R. C. Metcalf.* "Original nature with adequate stimuli does favor war between nations."—*W. S. Miller.* "There are present in human nature instinctive factors that make war between nations highly probable."—*D. G. Paterson.* "No, although the complexity and remoteness of a world order may be beyond average human comprehension. This would be absence of factors (not positive instinctive factors)."—*W. T. Root.* "No, but these factors are difficult to control, and a gain in one period is likely to be nearly lost by a later reversal. We have here simply a learning curve which, in the case of international stability, must be close to the origin and highly variable."—*G. S. Snoddy.* "Are present but not ineradicable."—*M. A. Tinker.* "As human beings we have common instincts. These can be increased into a common plan by ties of service that will banish the destructive war spirit. But this condition is still far removed."—*A. W. Trettien.* "No, but that does not settle the matter by a long shot. It is inevitability versus probability. And the probability may be very high, high enough for a very good bet, say, a 1000 to one."—*J. P. Turner.* "No. But I do not mean that the eradication of war will be easy."—*J. E. W. Wallin.* "Since war has many times in the past, through the operation of ineradicable, instinctive factors in human nature, been avoided, obviously it is not inevitable. If the following question be substituted: Do you think that instinctive, ineradicable factors will

ever make war between nations impossible for the rest of time, I would answer 'No.' Only economic pressure can make war impossible. Instinctive factors work both for it and against it."—*M. F. Washburn.*

In a personal communication, too lengthy to be included, an opinion was received, the gist of which seems to be that war, while formerly necessary for the preservation of the human species, has become atavistic, and, like a physical organ that "has played its rôle," would have disappeared but for the fact that it has been "pampered and cherished." This atavistic "war instinct has become the tyrant of humanity." If it can not be abolished "all civilized mankind will die out in a geologically very short period."—*L. Hoesch-Ernst.*

Of the 10 persons who voted in the affirmative 7 gave unequivocal answers without comment. Three gave answers modified as follows: "Yes, for a long time. Maybe could breed it out after a while—doubt if education alone would do it."—*H. E. Burtt.* "Yes, when operating through *crowd behavior*."—*L. W. Kline.* "Yes. This does not imply an 'instinct to make war.'"—*L. H. Lanier.*

Among the 22 who gave unclassifiable replies some had no positive opinion, and some gave equivocal answers, while others avoided categorical answers by introducing different questions and interpretations of their own. "Evidence insufficient to justify an opinion."—*K. S. Lashley.* Only one respondent denied that the problem was a psychological one: "This seems to me to be a problem for the historian of the future rather than for the psychologist of the present."—*G. H. Kent.*

It is possible that of these 22 unclassified answers 8 might legitimately be added to the 346 negative answers reported above. These are as follows: "Instinctive factors make contest but not war inevitable. The way to eliminate war is probably to eliminate nations."—*E. Culler.* "Under present conditions, yes. With suitable international laws and means of enforcement, no."—*C. W. Darrow.* "Yes, but not that make nationality inevitable."—*H. K. Nixon.* "A combination of factors."—*D. E. Phillips.* "Utterly impossible to answer categorically. There are apparently human tendencies which make for friction and strife (anger, fear, etc.) and other tendencies which make for peace. Education and social organization turn the balance."—*E. B. Skaggs.* "The instinct of self-preservation may be developed into an impulse to fight in every normal man and woman."—*M. K. Smith.* "I feel that much, if not all, of what causes war lies deep in original nature. What *universal* education may be able to do hath not yet been revealed."—*F. M. Teagarden.* "I believe *conflict* psychologically inevitable, but international warfare may disappear if our culture changes."—*K. Young.*

Conclusion

It is to be borne in mind that the question submitted did not inquire as to the existence or non-existence in human nature of pugnacious, competitive or predatory tendencies. Nor did it deal with the question as to whether or not conflicting claims and clashes of interests must continue to arise between nations. But, assuming that such conflicts of interest shall arise, the question asked whether or not the *mode of adjustment* of these conflicts is specifically pre-determined by inherited reaction patterns of a sort that must inevitably lead to war, as traditional opinion has maintained. The conclusion, which seems evident on the face of the returns here submitted, I venture to state in answer to the above questions as follows: Without raising the issue as to the inevitability of conflicting claims and interests arising between nations, American psychologists are almost unanimously agreed that the traditional opinion that instincts determine the mode of adjustment of these conflicts is without scientific warrant.

ARIZONA THROUGH THE AGES

By EDWIN D. McKEE

PARK NATURALIST, GRAND CANYON NATIONAL PARK

THE great desert region of the American Southwest finds much of its finest expression in the state of Arizona. Whether among the mountains, in the valleys or on the great plateau of that state the weird yet friendly landscapes have a character which a semi-arid climate alone can give. More remarkable then is the great diversity of land forms which make up the geology of this region. From north to south there are three large and vastly different areas. The high, level plateau of northern Arizona, with its mesas and tablelands, is in strong contrast to the rugged mountain area which extends from northwest to southeast through the central part of the state. Again, the famous basin range area of southern Arizona, where wide flat valleys are bordered by rugged mountain ranges, differs widely from either of the other provinces. Little wonder is it that geologist and artist alike find much to please them here.

The proverbial expression "eternal hills" is about as close to being both literally and figuratively correct when applied to the mountains of central Arizona as to any place in the world. "Rock of Ages" might perhaps be even more aptly ascribed to that ancient land, for the rocks which are responsible for much of its beauty are as old as any known to-day. They form what the geologist calls a "positive area"—a region which apparently has throughout history remained as high country and so evaded being covered by encroaching seas. While the whole of the present Colorado Plateau of northern Arizona and likewise most of the southern part of this state have been raised above and lowered beneath the level of the sea many times during the passing of geologic time, and have had great layers of sand, mud and lime deposited on their surfaces, the region of the Mazatzal Mountains, Prescott, and southwestward has with one probable exception stood aloof. For this reason it has aptly been referred to as "the ancient Mazatzal-land."

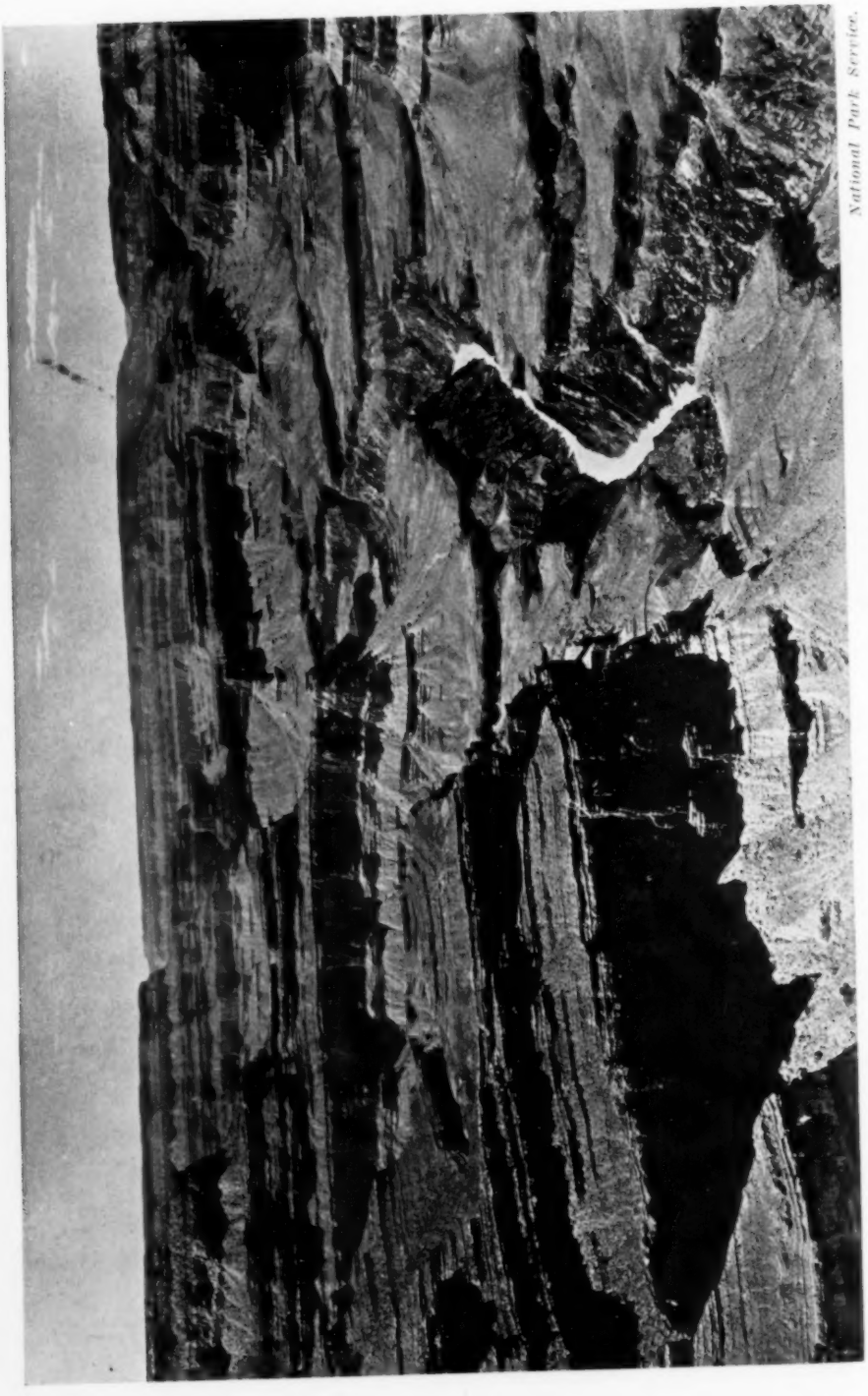
Crystalline rocks of the first era of the earth's history are found in Arizona not alone in the central mountain area, but also to the north at the bottom of the Grand Canyon and to the south, where they form the bases of many mountain ranges. Unfortunately knowledge concerning them is extremely limited, since they have been so contorted and compressed that both their original texture and composition have been altered. They stand to-day as monuments to the vast eons of time whose destructive powers they have survived.

Another great series of rocks—those of the second era—is also represented in many parts of Arizona. These, though only slightly changed from their original condition, and similar in most respects to rocks forming to-day, have yielded but little of the story of their origin and formation. As yet the only definite traces of life found in them are the reefs built by primitive types of plants.

The discovery in many parts of Arizona of very primitive forms of animal life preserved as fossils marks the beginning of the next—the third great chapter of geologic history. Not only do these fossils add much to our knowledge of ancestral life and to our interest in the rocks containing them, but also they often enable us to reconstruct, with the aid of a little imagination, a very definite picture of various ancient land-

BISBEE, THE COPPER TOWN,
SURROUNDED BY ROCKS OF EARLY GEOLOGIC PERIODS.

SCENE IN THE PETRIFIED FOREST NATIONAL MONUMENT.



National Park Service.

THE GRAND CANYON OF ARIZONA.

MUCH OF THE EARTH'S EARLY HISTORY IS REPRESENTED IN THE ROCK LAYERS OF ITS WALLS.

THE GILA RIVER
AMONG THE MESCAL MOUNTAINS, WHERE A FINE CROSS-SECTION OF GEOLOGIC HISTORY IS EXPOSED.

scapes of the past. We know, for instance, that large parts of the region were beneath shallow inland seas several times in that distant past and that many of the great strata of rock were formed as accumulations of limes, sands and muds beneath these seas. We know also that in the oldest rocks of this group are found only the traces of very primitive sea animals, such as shell types and crab-like creatures; that in those of later stages are found the evidences of early fish, as represented by plates or scales and teeth; and that in those rocks formed during the last part there are preserved very large forms of sea life in some places; and early land plants and four-footed animals in others. Truly, the succession and development of life as found in the series of strata of this chapter is striking. In northern Arizona it is extremely impressive as found in the upper two thirds of the Grand Canyon—layer upon layer as they were formed. Just as complete but less easily observed than the Grand Canyon series of strata are those found in many of the mountain ranges of southeastern Arizona. There the layers have been steeply tilted during mountain-making movements of more recent date, so that in order to travel from oldest to youngest one must traverse the mountains from east to west. Excellent examples of these cross-sections of history, replete with fossil life of many descriptions, are found near Globe, Tucson and Bisbee. Central and western Arizona alone remained as high country throughout practically all that great era while seas came in and retreated from the extensive basins on all sides many times. These scenes shifted continually, but always the low country was being built up, the high country eroded away, and life continued along its course of progress.

A visit to Arizona is scarcely complete without a trip into the beautiful Painted Desert in the north central

ROCK MADE OF FOSSIL SAND DUNES, PAINTED DESERT REGION.

MUCH OF THE EARTH'S EARLY HISTORY IS REPRESENTED IN THE ROCK LAYERS OF ITS WALLS. THE GRAND CANYON OF ARIZONA.

SANDSTONES AND MUDROCKS
FORMED IN SHALLOW WATER, BLUE CANYON.

part. Here one finds scenery which is unique in many respects. There are brilliant red cliffs, flat-topped mesas, rounded blue and green hills of marl, and many other peculiar land forms which give this region a character of its own. It seems very appropriate, therefore, that the rocks of the gaudy Painted Desert should have a spectacular and thrilling history of their own. They represent periods more recent by many millions of years than any of those already described. They were formed during the famous "age of dinosaurs," and are the results of vast accumulations of pebbles, sands, limes and muds. Some of the strata were formed beneath the sea and in them are found seashells of many varieties. Others are the deposits of ancient flood

THE PUEBLO OF WALPI
BUILT ON ROCKS FORMED BENEATH THE SEA.

OATMAN,

A GOLD-MINING TOWN, LOCATED AMONG ANCIENT VOLCANIC CONES.

plains or river deltas which have preserved the tracks and bones of dinosaurs and other ancient reptiles, as well as great logs of wood which were long ago turned to stone. In the Petrified Forest National Monument in northern Arizona may be seen some of the most spectacular and beautiful examples of such petrified logs found anywhere in the world. But scenes changed many times during that great chapter, and we find that each stratum has a very distinct though equally fascinating history. The sandstone of the Vermilion Cliffs, which forms the walls of Zion Canyon and out of which has been carved the beautiful Rainbow Bridge, was built up in a great desert area as the accumulation of sand dunes. Again, at a still later date the region was quite humid with the formation of coal beds along coastal plains. The rocks of lovely little Coal and Blue Canyons and the towering Hopi mesas bear witness of the presence of coal-forming and then marine conditions in this region. Only the

ON THE NAVAJO INDIAN RESERVATION.

MONUMENTS OF FORMER ERUPTIVE ACTIVITY AND REMNANTS OF EROSION.

SAN FRANCISCO MOUNTAIN, AN EXTINCT VOLCANO.

last part of the fourth great era is represented by the exposed rocks in other parts of Arizona.

The events of the fifth and last chapter of the earth's history are recorded throughout Arizona not in rock strata, as are the older ones, but by the great displays of volcanic activity and by the many wonderful features of erosion. Most of the long ranges of jagged mountains in southern Arizona, the lofty White Mountains farther north and east, and the cone-shaped San Francisco Peaks of northern Arizona, as well as many black lava flows and other characters of the landscape, are all results of eruptive activity during "the age of mammals." A few lake deposits of gravels and sands containing the remains of elephants, camels, bison and other extinct animals have been found, showing that such creatures roamed over the region not far back in history. But the greatest story of this most recent chapter is that of erosion—the wearing down of the high country throughout the state and the sculpturing of the landscape during a vast number of years. All the scenic features for which Arizona is noted to-day—its canyons, its mountains, its mesas and its valleys—are the results of the ever-working forces of erosion in this arid region, and due to their success the magnificent history of the older rocks, extending back through the ages, has been made available to those who care to read its chapters.

RARE BOOKS IN THE COAST AND GEODETIC SURVEY LIBRARY

By HUGH H. HARTLEY

LIBRARIAN, U. S. COAST AND GEODETIC SURVEY

AMONG the extensive collection of works regarding the major subjects of geophysics, assembled to aid the scientific personnel of the Coast and Geodetic Survey in the conduct of the duties with which it is charged by legislation, the technical library of the Coast and Geodetic Survey is the fortunate possessor of numerous rare old books on astronomy, geodesy, mathematics, mechanics, terrestrial magnetism and early voyages. Many are in a splendid state of preservation, including their original binding, vellum in some instances.

A large number of these rare book treasures were purchased in Europe in 1811 by Ferdinand Rudolph Hassler, the Swiss scientist who was the first superintendent of the Coast Survey (now Coast and Geodetic Survey), which had its inception in 1807 during the administration of President Thomas Jefferson. Some of these books have indorsed on the blank leaves preceding the title-pages, in the handwriting of Hassler, "Library for the survey of the coast," which at that time included only the Atlantic coast of the United States, approximately 1,658 statute miles in extent. The duty of performing hydrographic surveys, conducted for the purpose of making water navigation safe for humanity, its sustenance and wealth, greatly expedited through mod-

The LANDING *of* CAPT^N COOK, &c. *at* MIDDLEBURGH.

ILLUSTRATION OCCURRING OPPOSITE PAGE 498, VOL. II, COOK'S VOYAGES AROUND THE WORLD, LONDON 1790.[1]

[1] The author is under obligations to the U. S. Coast and Geodetic Survey for the illustrations in this article.

DRAWING OF TOPOGRAPHICAL SYMBOLS

OCCURRING OPPOSITE PAGE 54 OF LA SCIENCE DE L'ARCHITECTE DU DEPAS DE MONTESSON, PARIS 1755.

ILLUSTRATION OCCURRING OPPOSITE PAGE 986, VOL. III, COOK'S VOYAGES AROUND THE WORLD, LONDON 1790.

ern development of radio acoustic ranging, now applies to the entire continental and insular shore-line of the United States, 103,000 statute miles.

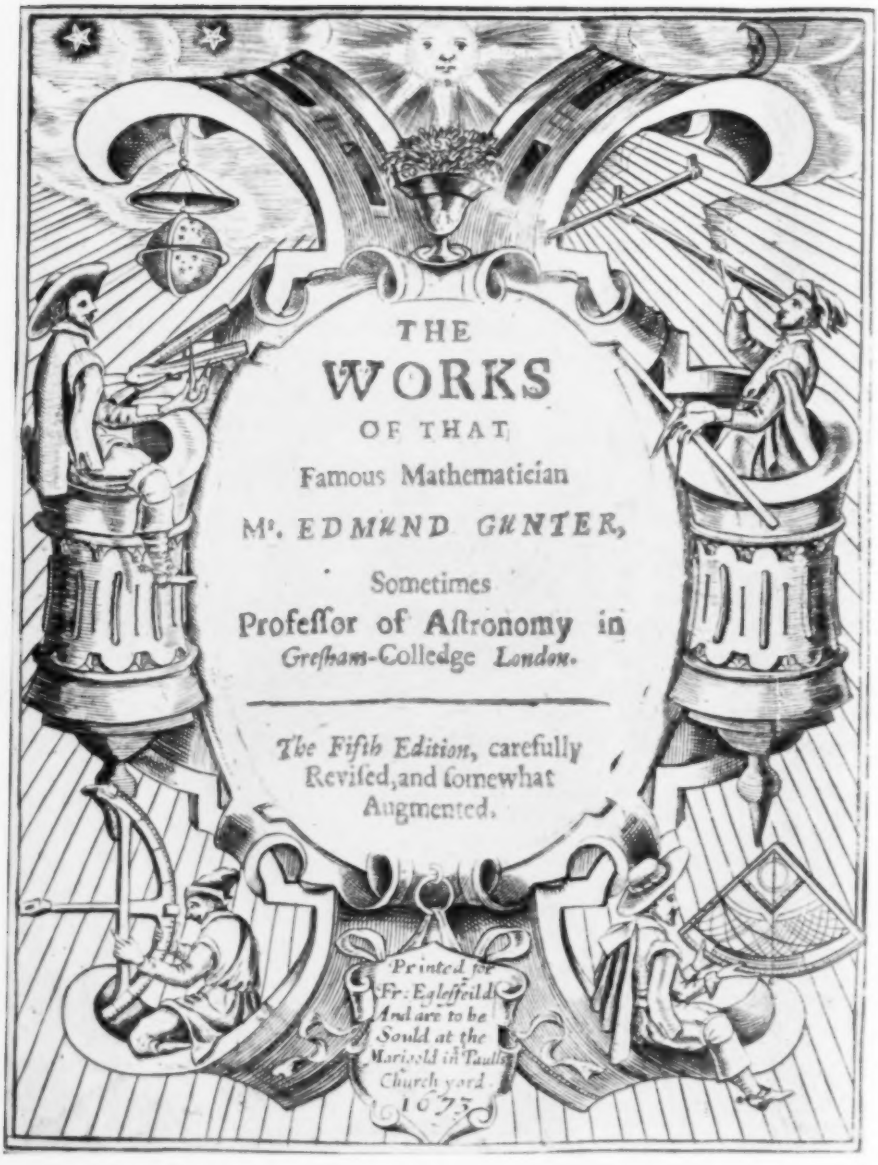
Of the original works purchased by Hassler, he said in part:

> When in 1811, F. R. H. was sent to Europe for the procuring of instruments and books for the Government, finding it proper on his part to use the public funds entrusted to him only for the greater objects of immediate want for the coast survey work, he bought on the Government's account only the closest needed books of those times. The books consisted of the best works on astronomy and geodesy, particularly useful for the instruction of the young officers intended to be employed in the work.

Many of these old volumes are profusely illustrated with practical delineations of the use of instruments for observation and surveying, graphic solutions of problems and the composite embellishment of title pages. Quaint designs in direct conjunction with the first letter of an initial paragraph of a chapter are interspersed through these works. A representative selection of these illustrations, photographed from the original, reproduced with this text, afford an idea of their ornateness.

Noteworthy among the astronomical works are three editions of the "Magnae Constructionis Mathematicae," opus of Claude Ptolemy, the Egyptian astronomer, whose great work has remained known by the superlative hybrid name "Almagest," so designated when it was first translated into Arabic A. D. 827 for the astronomer Caliph al-Mamun. The 1528 edition of this work was the first Latin translation made from the Greek first edition of 1451. The following translation of the title page of this copy shows the effusive encomium employed and the prohibition of printing by any other printer, which practice was the forerunner of our present day copyright law:

> The Almagest or the surely divine work of Claude Ptolemy of Alexandria, to wit, his great mathematical compendium of astronomy pre-



TITLE-PAGE OF THE FIFTH EDITION OF THE WORKS OF EDMUND GUNTER, LONDON 1673.

FRONTISPIECE TO TRAITE DES PRATIQUES GEOMETRALES ET PERSPECTIVES, ENSEIGNEES DANS L'ACADEMIE ROYALE DE LA PEINTURE ET SCULPTURE, PAR ABRAHAM BOSSE, PARIS 1665.

sented to the reader in the Latin tongue by the most learned George of Trebizond. Revised by Luke Gauricus of Naples, famous professor of celestial learning in the fostering city of Venice, mistress of the world, in the current year of our salvation 1528. In accordance with a decree of the Senate of Venice let no other printer in Venice or elsewhere in the dominions of Venice print the Almagest within ten years for fear of punishment.

Prominent among the early works printed in English text owned by the technical library of the Coast and Geodetic Survey is an excellently preserved copy of the fifth edition of the famous English mathematician, Edmund Gunter (1581–1626), "sometime professor of astronomy in Greshem-Colledge, London," "printed for Frank Eglesfeild . . . to be sould at the Marigold in St. Paulls Church yard 1673," edited by William Leybourn, who appended after his name "Philomath," indicating that he, too, was a lover of learning. The dedicatory epistle of this edition by Leybourn, addressed to "the right honourable John, Earl of Bridgewater, Viscount Brackley, Baron Ellesmore: one of the lords of His Majesties most honourable privie Council and Lord Lieutenant of the County of Buckingham," begins with highest praise for the works of the learned Gunter.

To-day Gunter, the Hertfordshire mathematician, is still revered by men of science for his scientific contributions and inventions, listed under his name in the fourteenth edition of the Encyclopaedia Britannica, of which the following are cited in part:

With Gunter's name are associated several useful inventions, descriptions of which are given in his treatises on the Sector, Cross-staff, Bow, Quadrant and other Instruments. In 1620 he published his Canon triangulorum. There is reason to believe that Gunter was the first to discover (in 1622 or 1625) that the magnetic declination at one place varies (see Terrestrial Magnetism). He introduced the words cosine and Cotangent (see Trigonometry), and he suggested to Henry Briggs, his friend and colleague, the use of the arithmetical complement (see Briggs' Arithmetica Logarithmica, cap. xv., and Logarithms).

His practical inventions are Gunter's Chain, the chain in common use for surveying, 22 yd. long and divided into 100 links;

Gunter's Line, a logarithmic line, the forerunner of the slide rule;

Gunter's Quadrant, used to find the hour of the day, the sun's azimuth, etc., and also to take the altitude of an object in degrees: and

Gunter's Scale (generally called by seamen the *Gunter*), a large plane scale, engraved with various lines of numbers and used to solve problems in navigation, trigonometry, etc., with the aid of a pair of compasses.

Of probable interest is the quaint advertisement quoted hereafter from the fifth edition of the "Works of Edmund Gunter," which, though not accompanied by any attractive design, was perhaps just as effective for those times as is the multiplicity of modern advertisements:

Whereas the whole subject of the following Treatises do contain the use of Instruments, and that the true and exact making of them is principally to be minded and enquired into, I thought good to give notice, That if any Gentlemen studious in the Mathematicks have or shall have occasion for any Instrument belonging to this Book, as also with all others useful both for Sea and Land, they may be furnished either in Silver, Brass, or Wood, by Walter Hayes, at the Cross-daggers in Moor-fields, next door to the Pope's-head Tavern; where they may have all sorts of Maps, Globes, Sea-plats, Carpenters Rules, Post and Pocket-Dials for any Latitude, &c.

The illustration reproduced elsewhere in this paper headed, "Le Spectacle de la Campagne" (the appearance of the country), from the book, "La Science de L'Arpenteur" (the science of surveying), by M. Dupain De Montesson, Paris, 1765, indicates an authentic source for the comparison of the earlier delineation representing the prominent terrain features with many of the modern related symbols employed in the production of topographical and tactical maps. In some instances the comparison discloses that many of the modern symbols of configurations are similar to

M. DANIEL SCHWENTER NORIB. LINGVAE S. PROF. ET MATHEM. CVLTOR Apud Altorf: Ætatis suæ 38. A° 1623.
EVCLIDES
Lucas Kilian. fecit
Qvod Teuto, Ausonius, qvod Graius, Hebræus, Arabsq;,
Qvod Syrus, Assyrius fatitur, multi: unius omne
SCHWENTERI à lingva manat. Qvid; qvòd docet artem
Euclidis; tum qvæ mysteria âocta mathesis.
Suggerit. HVNC spectandum obfert heic Cous Apelles.

PORTRAIT OF M. DANIEL SCHWENTER,

NUREMBERG LINGUIST AND MATHEMATICIAN, AT 38, BY THE ARTIST APPELES, OCCURRING OPPOSITE PAGE 1 OF TRACTUS II, GEOMETRIAE PRACTICAE NOVAE ET AUCTAE, 1641. (ORIGINAL VELLUM BINDING).

FRONTISPIECE TO DE ARITHMETICAE ET TRIGONOMETRIA ET GEOMETRIA, BY ADRIANUS METIUS, LEYDEN 1626.

(THE U. S. COAST AND GEODETIC SURVEY COPY IN ORIGINAL VELLUM CONTAINS THE FOLLOWING NOTE: "FROM THE LIBRARY OF THE ANCIENT AND NOBLE FAMILY OF FAIRFAX, COMPRISING THE MANUSCRIPTS OF THE FAMILY AND THE CORRESPONDENCE OF SIR THOMAS FAIRFAX, PARLIAMENTARY GENERAL DURING THE CIVIL WARS, AND AUTOGRAPH LETTERS OF OLIVER CROMWELL AND THE GREAT LEADERS OF HIS TIME. PAPERS OF HIS SON-IN-LAW, GEORGE VILLIERS, DUKE OF BUCKINGHAM, AND UNPUBLISHED COMPUTATIONS OF THE FIRST LORD SIR THOMAS FAIRFAX AND OTHER EMINENT PERSONS OF THE NAME WERE COLLECTED IN THE ANCIENT LIBRARY OF LEEDS CASTLE.")

those used during the early part of the eighteenth century. Others show features that closely resemble those occurring in many of the present-day aerial photographs. In fact, it is not difficult to visualize that the earlier etched symbols appear as though they might have been copied from some recent aerial photographs.

Illustrative of this is an incident where library employees at first glance mistook for an aerial photograph a bromide copy of a map of "Afbeeldinge van de Stadt Amsterdam in Nieuw Neederlandt" (drawing of the City of Amsterdam in New Netherlands), drawn in 1665 by Jacques Cortelyou. This map was precisely drawn as though the artist were looking down on the scene at an angle of 60 degrees. This copy was sent to the late Colonel E. Lester Jones when Director of the Coast and Geodetic Survey, by Comte Cosimo Rucellai, former minister of instruction, Florence, Italy, as a result of their meeting during the session of the International Geographical Union held at Cambridge, England, from July 17 to 25, 1928.

This particular map is included as Plate 82 in Volume II of the "Iconography of Manhattan Island," 1498–1909, by J. N. Phelps Stokes; published by Robert H. Dodd, 1915.

In litigation involving property and riparian rights, early Coast and Geodetic Survey maps of areas of the coastline involved are referred to in court proceedings in cases sometimes involving several million dollars, as an authentic source for the adjudication of such cases. These early maps in turn must necessarily have an authority to fall back on, particularly with reference to the various topographical symbols employed. Therefore, it can be readily understood that the aforementioned group of topographical symbols entitled, "Le Spectacle de la Campagne," is recognized as an authoritative source. As a case in point, some question arises concerning a stretch of land extending from the mainland, narrow for some extent and then expanding to a shape of land indicative of the fact that this stretch of land appears to be an island with the exception of the narrow connection between it and the mainland. The adduced facts disclose that at one time this stretch of land near the shore was a marsh covered by water at high tide, and that by reason of its being filled in by the city the semblance of an island at high tide has been subsequently eliminated. The tiny topographic symbols on early maps indicating the existing condition of the terrain at that time can be resorted to to prove that this stretch of land was at one time an island connected with the mainland by a marshy area.

Every precaution is taken to preserve these rare volumes against too rapid disintegration brought about by the ravages and vicissitudes of climate, time and usage. Consultation by scientists and serious students of these rarities is permitted in the library.

THE PURPOSE OF TIDE OBSERVATIONS

By H. A. MARMER

U. S. COAST AND GEODETIC SURVEY

Our federal government, through various of its agencies, is engaged in a great variety of technical and scientific activities. The purpose of many of these is clearly apparent from their names. Investigations for the control of hog cholera, studies on the propagation of food fishes, forest research, testing of structural materials—the intent of these is defined by their designations.

The purposes of other technical and scientific activities, however, are not so clearly evident from their names. The government is engaged in making tide observations. What is the purpose of these? To be sure, the tide is an interesting phenomena and has engaged the attention of philosophers and scientists for many centuries. But this scientific interest, obviously, is not sufficient reason for the government assuming the study of tides.

Tidal investigation in this country arose almost wholly in pursuance of aims of a practical nature. In 1807 the Coast Survey was established for the purpose of charting the coast. Immediately the need for tide observations became apparent. For the boundary between land and sea shifts continually—landward with the rising tide and seaward with the falling tide. Furthermore, the heights attained by high water and low water at any place vary from day to day. In fixing the boundary between land and sea these tidal features must clearly be taken into account.

Again, in determining the depths of the water in the region covered by a chart, depth measurements, or soundings as they are usually called, are made. But these depths, as actually measured, do not correctly represent the depths in the region; for the soundings are made from the surface of the sea, the level of which is constantly changing under the influence of the rise and fall of the tide, and of the disturbing effects of wind and weather. To determine the correct depths from the soundings they must be reduced to some uniform level or fixed datum plane.

Begun thus as an incidental detail in connection with its hydrographic and geodetic surveying, the tidal work of the Coast and Geodetic Survey has gradually expanded in scope and assumed larger proportions. This expansion became necessary both in meeting the various problems arising from its own primary surveying operations, and in meeting the demands made by other governmental agencies and by the public generally. Quite apart from the closely related work dealing with tidal currents, the purposes now served by the tidal work of this bureau may be classed under five heads as follows: (a) determination of datum planes; (b) establishment of tidal bench marks; (c) publication of tide tables; (d) maintenance of records of rise and fall of tide; (e) study of tides and tidal phenomena. What is comprised under each of these five heads is described briefly below.

Datum Planes

The necessity for datum planes in connection with harbor and coast charts has already been mentioned. As a rule some low water plane such as mean low water, mean lower low water, or low water springs is adopted for such charts, and such datums can be determined only by means of tide observations.

For charting depths in the sea, and more specially in coastal waters, the

necessity for a tidal datum plane is clear; but for reckoning heights on land it would appear at first thought as if the tides were wholly out of consideration. And for a time heights on land were reckoned from local arbitrary datums, this procedure involving no difficulties, so long as the country was sparsely settled and communities isolated. However, when lines of levels carried from such arbitrary datums met, confusion was inevitable. And this confusion became compounded with the expansion of the country and with the growth of large urban centers.

A further difficulty in connection with the use of arbitrary datum planes for reckoning heights on land arises when it becomes necessary to recover such datum planes. If the point originally chosen as defining the datum is changed or destroyed it frequently becomes impossible to recover the datum used, and surveys based on such datums can not be correlated.

The desirability of a uniform datum for reckoning heights on land is obvious. Such a datum should possess the further advantage of certainty of recovery, even though all bench mark connections be lost. These advantages are furnished by the datum of mean sea level. Heights on land, whether along the coast or in the interior of the country are now reckoned from mean sea level. All civilized nations are spreading lines of precise levels throughout the territories under their jurisdiction for the purpose of making this datum available in all sections of the country. And like the low water datums used in harbor and coast charts, the datum of mean sea level can be determined only by means of tide observations. From the coast, where this datum is established by the tide observations, the engineer carries it throughout the land by means of spirit levels.

For other purposes other datum planes are used. In connection with the development of lands fronting the seashore, the datum of high water is of importance. And at certain places distinction must be made between the datums of mean high water, higher high water, and storm high water. All such datum planes, too, can be determined only by means of tide observations.

In connection with datum planes that may be used as planes of reference, both for heights on land and depths in the sea, it is to be noted that those based on the rise and fall of the tide possess the advantages of simplicity of definition, accuracy of determination, readiness of correlation, and certainty of recovery even though all bench mark connections be lost. It is for these reasons that datum planes defined by the tide are used in engineering and in other technical and scientific work.

If the rise and fall of the tide were exactly the same from day to day, the determination of a tidal datum plane would be a very simple matter. Any low water would determine mean low water, any high water mean high water, and one day of observations would determine mean sea level. But high water, low water, and sea level vary from day to day, from month to month, and from year to year. It was therefore necessary to study the fluctuations to which the tide is subject in order that accurate datum planes might be derived.

It was found that the primary fluctuations of the tide go through a cycle of about nineteen years. In other words, to determine accurately the tidal datum planes at any place requires nineteen years of observations. But this is a very considerable period of time; and if nineteen years of observations were necessary to derive the datum planes at all places where these are required, the practical problem would be a very formidable one. Could not methods be devised by means of which the results from short series of observations might be reduced to mean values? Further study of the tide proved that this could be done, and now

datum planes may be determined with considerable precision from observations covering a year of observations or even less.

Bench Marks

From the tide observations made at any point, the various datum planes are determined as corresponding to certain heights on a fixed tide staff used in making the observations at that point. In other words, these datum planes at that point are specified as so many feet and hundredths above the zero of a given tide staff. And if it were a simple matter to maintain that tide staff for many years without change in elevation, it would serve very well for preserving the determination of the different datum planes.

But unfortunately it is very rare that a tide staff remains undisturbed for a number of years. Deterioration of the material of which it is made, changes in wharves and piling, and accidents of one kind or another are certain to occur. And unless some means are used for preserving the datum planes determined by a given series of observations, these would be lost in the course of time. It is this purpose that tidal bench marks serve.

Tidal bench marks, established in rock or concrete, or on some substantial structure, preserve the datum planes derived from a series of tide observations. By connecting these bench marks, by means of spirit levels, with the zero of the tide staff, the relation of the various datum planes to the bench marks becomes known. A number of bench marks are established in connection with the tide observations in a given locality so that even if several are destroyed with the passing years, others will remain. With this thought in mind, too, the bench marks are scattered to insure against loss from a common cause.

At hundreds of places along the coasts of the United States, bench marks have been established. The descriptions and elevations of these are being published in pamphlets which are available to the engineer, the geologist and others interested. From time to time, as opportunity affords, these bench marks are inspected and releveled, and new ones established to take the place of any that have become displaced or destroyed.

Tide Tables

On the charts which the mariner makes use of in navigating his ship, the depths shown refer to some fixed low water datum. But the depths he will actually find at any given time depend on the state of the tide. With the shallow-draught sailing vessels of an earlier generation there was generally a sufficient depth of water in most harbors and important channels at all stages of the tide, and the navigator therefore troubled himself but little in regard to the state of the tide.

Now, however, with the deep-draught vessels of modern commerce approaching the depth of the water over bars and in channels leading to important ports, the state of the tide becomes a matter of vital importance. The cost of operation of a modern vessel and the exacting schedules to which modern shipping is subject make it a serious matter for a vessel to lie several hours outside a harbor awaiting a favorable tide. The navigator, whether of a merchantman or of a man-of-war, now must have advance information in regard to the state of the tide in the regions which his vessel is to traverse.

This advance knowledge of the state of the tide is furnished the navigator through tide tables which give predictions of the times and heights of the high and low waters for each day of a year at the most important harbors. Each of the leading maritime nations issues tide tables, and for the United States this

work devolves on the Coast and Geodetic Survey. Early in the summer of each year this bureau issues a volume of some 400 pages which foretells for every day of the following year the times and heights of each high and low water at 94 of the principal ports of the world. In addition, data are given for more than 3,000 other places, which in connection with the daily predictions for the 94 principal ports, permit the navigator to predict the tides also for these places.

If the tide were the simple phenomenon that one might be led to infer from the treatment of the subject in our textbooks on astronomy or physical geography, the prediction of tides would be a simple matter. Indeed, in the earlier tide tables, which were restricted to ports on the Atlantic Ocean, the predictions were made by very simple methods, since the tides in this ocean are relatively simple tides. But when it was found necessary to extend these tide tables to cover ports in the other oceans, difficulties were encountered. Not only do the times and heights of the tides at different places differ, but the very character of the rise and fall of the tide is found to exhibit almost bewildering variety.

In the Atlantic Ocean there are at most places two high waters and two low waters in a tidal day of 24 hours and 50 minutes. Furthermore, morning and afternoon tides are much the same in height and in other characteristics. And while the times and heights of the tide at these places vary somewhat from day to day in accordance with the changing positions of the moon, these variations are relatively small. In other words, the tides of the Atlantic Ocean are relatively simple tides.

But when we come to predict the tides for Seattle, Washington, it is found that while there are two high waters and two low waters each tidal day, morning and afternoon tides are quite unlike. The two high waters are found to be much alike but the two low waters differ—at times by as much as 8 feet. At Honolulu, on the other hand, the two low waters of each day are much alike, but the two high waters differ. And at San Diego both the high waters and the low waters of each day differ.

This does not exhaust the variety in tides. For at Pensacola, Florida, there is only one high water and one low water each day, while at Galveston, Texas, part of the time one high water and one low water occur in a day, and at other times two high waters and two low waters occur. Similar tides are also found at other places.

That the movement of the tide is in some way intimately connected with the movements of the moon has been known for centuries. This fact finds expression in the colloquial dictum that "the tide follows the moon." As a general statement this is true, but there are places where this relation does not appear to hold. At Tahiti, the tide appears to follow the sun, both in the times of high and low water. And at Jolo, in the Sulu Archipelago of the Philippine Islands, the high waters follow the moon, but the low waters follow the sun.

In solving the practical problems of tide prediction for the different kinds of tides, it was necessary to study tides and tidal phenomena in order to arrive at an understanding of the causes and factors involved. That such study has been successful is evidenced by the fact that methods and instruments have been evolved by means of which the most complicated tide can now be predicted by means of mechanical tide predictors.

Tide Records

In connection with the varied activities of modern life it becomes important at different times to ascertain the state of the tide at some past time. Admiralty cases involving the collision or the grounding of a vessel; cases affecting title to lands fronting on the water, the boundaries of which frequently refer to

high or low water; damage to property during some exceptionally high tide; cases involving changes in the rise and fall of the tide consequent on harbor improvement—all these demand observation data on the rise and fall of the tide. This means that some agency must maintain a file of tidal data which shall be taken as authoritative.

At certain selected points along the coasts and inland tidal waters of the United States, the Coast and Geodetic Survey maintains primary tide stations at which continuous tide observations are being obtained by means of automatic tide gauges. Since the appropriation for the tidal work is limited and the coast line considerable, it is the policy of the bureau to operate as many of these tide stations as possible on a cooperative basis with other governmental, state, or municipal agencies. By this means a uniform standard of precision is maintained in the tide work throughout the country at a minimum of cost.

The tide records from the primary tide stations constitute a primary source of the data on the rise and fall of the tide in their respective localities. By means of these records, too, it is possible to compute with reasonable confidence the state of the tide at other places some distance away. Thus with about thirty primary tide stations along the three coasts of continental United States it is possible to secure observations that cover the country in a fairly satisfactory manner.

The tide records obtained from the primary tide stations serve not only the purposes specified in the first paragraph of this section, but also other purposes as well. The data so obtained are used also in the tidal control for hydrographic work and in correcting to mean values the results from short series of observations. They furnish also the basic data for the study and advancement of the subject of tides and tidal phenomena.

Tides and Tidal Phenomena

As in other fields of technical work, it is virtually impossible in connection with tides and tidal phenomena to draw the line between the technical and the scientific, between the practical and the theoretical. Starting from the practical need of correcting soundings for the rise and fall of the tide, it became necessary to study the whole subject of tides and tidal phenomena in order that the practical purposes which the tide observations serve might be carried out most economically and most efficiently.

Throughout the world, almost without exception, tidal work is carried out by governmental agencies in connection with other public work. As a consequence there is in each country but one small organization engaged in this work. This means that improvements in methods and instruments can not be looked for on the outside; these must come from within the small groups engaged in that work. For this reason it becomes necessary to engage in research not only that the tidal work may keep abreast of the times, but more especially that the demands made by other fields of technical work, which are growing constantly, may be met efficiently. This research in turn necessitates a study of the subject of tides and tidal phenomena in all its phases.

As a branch of pure science, the theory of tides falls within the domains of celestial mechanics and hydrodynamics. And in these abstruse theoretical subjects it is the world's great mathematicians that have led the advance. But in the development of the technical work designed to carry out the practical purposes of tide observations it is the tidal specialist, or the tidal engineer as he is now known, who has had to shoulder the burden.

To carry out these practical purposes he has been compelled to study the whole subject of tides. Why do the tides in

the arm of the sea known as the Gulf of Maine and the Bay of Fundy differ so greatly in height, one foot on Nantucket Island to more than 40 feet at the head of the Bay of Fundy? Why are the tides in the Atlantic so much simpler than in the Pacific and Indian Oceans? Why are the tides at the two ends of the Panama Canal so strikingly different? As the crow flies, the ends of this canal are but little more than thirty nautical miles apart, yet at the Atlantic entrance the rise and fall is less than a foot on the average, while at the Pacific end the rise and fall averages more than 12 feet. Why the peculiar behavior of the tide at Tahiti, where it appears to follow the sun rather than the moon? Why one high and low water in a day at one place and two high and low waters at another?

These are but a few illustrative examples of a great variety of questions with which the tidal specialist is confronted. Altogether aside from their scientific importance, which could not but help enlist the interest of the trained worker, the necessity for solving the practical problems involved compelled research. As a result, the tidal specialists in government employ have a very considerable body of scientific research in tides to their credit.

The different purposes for which the tidal work of the Coast and Geodetic Survey is carried on are obviously not mutually exclusive. Indeed, they fit in so well with each other that operations carried on for one purpose at the same time serve the other purposes. At the basis of all tidal work and research, however, lie the field observations on the rise and fall of the tide.

Some Collateral Uses of Tide Observations

The purposes described above are the primary purposes for which tide observations are being made by the federal government. The data derived from these observations, however, lend themselves to other purposes of a less immediately practical nature. Take the question of coastal stability. For a number of years it has been taken for granted that the Atlantic coast of the United States is subsiding at the rate of about two feet per century. The evidence upon which this conclusion was based was of various kinds. Indian shell heaps are now found below high tide level; tree stumps are found in place in salt marshes, indicating that the trees were killed by the invasion of salt water; salt-water marshes appear to have encroached upon the upland areas. These and similar facts are taken to indicate a gradual subsidence of the Atlantic coast of the United States.

This evidence, however, is not at all conclusive. Certain competent students of the problem regard the facts cited as capable of interpretation in other ways, without invoking a subsidence of the coast. But if there were at hand systematic tide observations for the past century, the question could be answered conclusively. For if the coast were subsiding, sealevel would now stand higher than formerly. Unfortunately, the earlier tide observations were made for purposes of an immediately practical nature, and do not lend themselves to study for this purpose. But with the continuance of the systematic observations now in progress, the data will furnish conclusive evidence in regard to coastal stability, a question obviously of very great importance.

On the open coast the tide is an agent of geologic change. The coast line, as the term is ordinarily used, is supposed to mark the boundary between land and sea, and on the small scale maps which are generally used it has a deceptive appearance of precise location. In reality, however, the term is a misnomer, for land and sea meet, not in a line, but in a zone marked by shifting boundaries

of varying width. This zone belongs now to the sea and now to the land. At low water the land extends farther seaward and at high water the sea encroaches on the land. At times of neap tides the width of this zone is much reduced, while at times of spring tides it has its greatest width. This zone is frequently called the foreshore.

Now the foreshore is the scene of constant warfare and change. Here wave and current have their greatest effect in their attack on the land. At one point the land gives way slowly to the sea under the constant beat of the waves; at another point the turbid waters are relieved of their load of sediment to form a bar or spit which the land finally redeems from the sea. The tide thus enters as a factor of geologic change along the coast. And in the study of shore-line changes, tide observations furnish the data necessary in evaluating the share of the tide.

Along the coast and in inland bodies of tidal water, the biologist must reckon with the tide in the problems that confront him. For to the plant and animal life in tidal waters the distribution of temperature and salinity is of great importance. And in this distribution, the tide plays an important part in the constant interchange which it effects between the coastal waters and the waters of the open sea. In this field of investigation, too, tide observations furnish basic data.

Going farther afield it is found that the tide enters into a great variety of problems as a factor that can not be neglected. Many of these problems appear at first glance to have nothing to do with the tide. Such questions as the rigidity of the earth, the apparent secular variation of the moon, the change in the rotational velocity of the earth—questions which clearly fall within the domain of the geophysicist, the astronomer and the cosmogonist, and appear to be far removed from tides. Yet in the investigations of these matters various facts are encountered which can be interpreted only through a study of the tide.

An enumeration of all the fields of investigation into which tides enter as important factors would make a long list—altogether too long for the present article. All that is intended here is to direct attention to the primary purposes for which tide observations are being made, and to point out that in serving these purposes they lend themselves also to investigations in other fields. It must be emphasized, however, that to secure full value from such observations they must be made systematically and continuously. Fortunately such observations can be secured at very little cost by the use of automatic tide gauges.

THE CRIME OF ARCHEOLOGY—A STUDY OF WEATHERING

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Introduction

The observations and conclusions in this paper are the result of brief visits to some of the more important sites of Greek and Roman antiquity during the summer of 1931. As a geologist, the writer was especially interested in the effects of the weather on ancient buildings, sculptures, and carvings, and it is to the disintegration of ancient art by this agency that attention will be called.

Anyone who has even an elementary knowledge of the art and architecture of ancient Greece and Rome and of older or contemporary peoples who have directly or indirectly contributed to the development of these great civilizations will appreciate the desirability of preserving for all time as much as possible of what remains of the works of these ancients.

Most archeologists in their desire to display their discoveries to the world fail to realize that exposure to the weather soon utterly destroys the works of man. They also fail to take into account the fact that, in general, destruction takes place at an increasingly rapid rate as checks and cracks are opened in weathering, so that a column, for example, which may show little evidence of weathering at the end of a hundred years may be greatly disintegrated at the end of a second century.

The archeologist does not seem to appreciate fully that in his desire to show his contemporaries what he has discovered, he is compelling future generations to depend, more and more with the years, upon written descriptions and illustrations for their knowledge of the works of antiquity.

Typical Examples of the Effect of Agents of the Weather

Striking and distressing examples of this thoughtlessness of archeologists can be seen in many places in the Mediterranean Basin. At Cnossus, for example, the thin slabs of coarsely crystalline gypsum which were cut by the ancient Minoans and used as wainscotings and pavements have been cleared of débris, and, already, many of them have been warped and broken. In a generation or two they will be reduced to sand and will be recognized as slabs with great difficulty.

The effect of the exposure of mosaics and frescoes to the blistering heat of the sun, the cool of the night and to soaking rains is already apparent in many excavations in the Mediterranean Basin. It has been observed that the mosaics of Delos are faded after a few years' exposure to the sun. At Carthage not only are the mosaics exposed to the sun, but some of them are the stamping grounds for herds of goats.

The floor of one of the basilicas in the Forum at Rome contains the remains of copper coins which adhere to the surface as a result of the heat of a fire which destroyed the building. The only protection given to these objects are a few loose boards, which are moved by the guide when he shows the pavement to visitors.

When Delphi was excavated the archeologists did a splendid piece of work, judged by their standards. They uncovered every column, every inscription, every carving and foundation stone that nature had so carefully preserved. Everything, in fact, is exposed, and the

destructive work of the weather is at a maximum. The interesting notices in small Greek characters which tell of the freeing of slaves are in walls where they must inevitably rapidly become illegible.

Although the Temple of Apollo at Delphi was finally restored at the beginning of the third century of our era, almost nothing remains *in situ* but fragments of pavements and the foundation stones. This destruction was brought about largely by the weather, assisted, possibly, by earthquake shocks.

In 1918, an underground basilica of the second century of our era was accidentally discovered in Rome. When first opened to the public, the monument was most spectacular with the entire surface of its vaults, walls and piers covered with pure white stucco reliefs which glistened in the artificial light. Now, less than fifteen years after its discovery, the monument is almost a wreck. Moisture has seeped through and has discolored the stucco and has loosened it so that, already, large patches have fallen off. In a few years, what was once a superb example of the stucco worker's art will be a complete ruin.

In Great Britain where the effects of the weather on stone should be apparent to every one; where it is said, that the building stones of the exterior of Westminster Abbey have been replaced five times, and where many of the stones of the comparatively new Parliament Buildings are already badly weathered, even here one finds ancient carvings and fragments of statuary exposed to the elements in churchyards. The same disregard of the inevitable effects of the weather is everywhere apparent in France and nearly every other country in Europe and the Americas. A study of the modern statuary in the Tuilleries garden in Paris will convince any one of the destructive work of the weather within a few generations in that city.

When, in 1811, Lord Elgin disregarded the right of the Greeks to their own works of art, and removed the statues of the pediments of the Parthenon to England, he was justly criticized for his lack of ethics. But, if these superb works of art had not been protected from the weather, as they have been in the British Museum, they would now be so badly weathered that little if any of their beauty would have remained.

The excavations at Delos by the French have uncovered many interesting things: mosaics, columns, foundations, statuary, stucco and painted wall decorations. Only a few people visit this ancient shrine of Apollo each year. Nevertheless, mosaics, columns, carvings, stucco and painted walls are left to the mercies of relentless forces which are rapidly destroying them.

The only protection of the thirty-five century old hearth of Agamemnon at Mycenae is a thin layer of earth which can be scraped off with the toe of the shoe.

Ancient Troy will not have suffered greatly from the work of the archeologist because, on account of its situation on the edge of a plateau overlooking the fertile plain of Troy, wind-borne sand and soil is rapidly filling in the excavations where it is being held by a luxuriant growth of thorny plants.

Mussolini, in his laudable ambition to make of Italy the most interesting and desirable spot in the world, has spent great sums of money in excavating and restoring ancient monuments and buildings. Noble as this purpose is, the result will be the eventual total destruction of these works of antiquity. A typical example of what may be expected is to be seen in the work which was done at Hadrian's Villa shortly before Mussolini came into power. Some walls were restored, and mosaics and marble inlaid floors were uncovered. Everything possible was done to make it interesting to the people of the present.

If this policy is continued for many

years, restoration will follow restoration until the history of Hadrian's Villa and other Roman ruins will be somewhat like that of Benjamin Franklin's famous cider barrel. According to the story, when the original heads of the barrel rotted away, they were replaced by new ones. When the staves rotted or broke, they were replaced one by one. At last, the only part of the original barrel which remained was the bung hole.

The Instructive Story of Olympia

Nature both destroys and preserves. If it had not been for an earthquake, landslides which dammed a river, and the flooding which resulted from the breaking of this barrier, little would have been left of the remains of ancient Olympia. The history of this center, which for more than a thousand years was the national center of Greek religion and the scene of the greatest athletic festival the world has ever known, is in brief as follows:

The first Olympiad is usually placed at 776 B. C., and the games were celebrated at intervals of four years until 393 A. D. In 394 A. D. they were abolished, and in 426 the destruction of all pagan temples was decreed. For nearly or quite a hundred years the temples, from time to time, were plundered of their marble columns and statuary, and easily removable fragments of marble were burned for lime, as is shown by the discovery of an unburnt charge in a limekiln which contained the heads, arms and legs of ancient statues.

In 522 and 551 A. D. the Peloponnesus was shaken by earthquakes. One or both of these shocks overthrew the temple of Zeus, and the great drums of the columns of the temple now look like piles of gigantic checkers which had toppled over. During the second of these earthquakes, great masses of land slid from the sides of the steep hills into the valley of the Kladeos River, forming a dam. The pressure of the rising water behind this dam eventually became so great that it burst through this barrier, carried great quantities of sediment and spread it over the western part of the temple area. Later, other floods deposited more sand and gravel until the temple area was buried in places to a depth of twenty feet. Then, for more than a thousand years, the foundations, the lower parts of the walls and the overthrown columns were comparatively safe from the destroying hand of man and nature. Not entirely safe because it was used as a quarry by the Turks and later inhabitants. For example, in 1766, "the walls of the cella of a great temple standing many feet high" was reported, but thirty-nine years later the walls were said to be only two feet above the ground.

The first archeological excavation was carried on in 1829, but it was not until 1876 that the careful work of the German archeologists had brought to light the foundations and walls of the temples as we see them to-day. The great volume of sand and gravel which covered the Altis or Temple Area was carted to the river, which in turn transported it to the sea.

The archeologist's work at Olympia is nearly done. He has measured and mapped the ruins. He has removed the more important pieces of statuary and architectural fragments to museums. He has made models and innumerable drawings. He has expounded his theories and has left for posterity a complete and beautifully illustrated description of his labors. The ruins now lie exposed to the weather and are visited by a relatively few people each year, only a few of whom "know what it is all about." The River Kladeos may again come to the rescue and conceal the remnants of the temples with a protecting cover of sediment so that future generations of scholars may again excavate and have the pleasure and profit of seeing the actual architecture of ancient Greece.

If, however, the ruins are left uncovered, column, wall and foundation will gradually disintegrate, just as has the gleaming white temple of Poseidon on beautiful Cape Colonna. The destruction will not be as rapid as in the latter, which is "melting away" so speedily that a visitor after an absence of five or six years is painfully aware of the disintegration which took place in that brief interval, but it will as surely disappear.

Suggestions and Comments

If the assumption of the writer is true that works of antiquity should be preserved for students of the distant future, that students of to-day should not deprive men and women who are to live after them of the privilege of seeing and studying the objects which ancient man made, it is obvious that archeologists should hesitate to undertake more excavations unless they can be reasonably certain that the objects they uncover can be preserved for people of the very distant future.

Objects in Museums

It is generally assumed that an object placed in a museum or under shelter is safe from disintegration. A study of objects now in museums and other buildings will show that not only wood but even stone and bronze may decay. A striking example is that of the so-called Purbeck Marble used in the Richard Beauchamp monument in St. Mary's Church, Warwick, England, and in several other English churches. The fossils which constitute a large part of the stone have loosened and fallen out to such a degree that the stone is nearly ready to fall apart.

Another similar object lesson is to be seen in the New York State Capitol, at Albany, in which some of the many narrow marble slabs in one of the halls are already showing signs of decay. Curators of museums are fully aware of the decay of objects under their care.

The Desirability of Refilling Excavated Sites

Attention has been called to the destruction—some rapid, some slow—of objects exposed to the weather. Every archeologist must be aware of the fact that in a few centuries the carvings, flutings and even the form of column and cornice will have wasted away, if they are left as they are now. This being true, should they say in effect: "This is an unfortunate circumstance but it was necessary if the world was to learn of these things." The correct answer seems obvious. If an excavation is to be made, as, for example, the new excavations of the American School of Classical Studies at Athens in the Agora, arrangements should be made in advance of the excavations to refill the excavations as soon as all that can be learned from them is obtained. Any statuary or other work of art should not be removed unless it is probable that these objects will be kept in their present condition for a thousand years.

The refilling of excavations should, however, not be begun until it has been learned what kind of a cover will best preserve the archeological remains. For example, if the Hermes of Praxiteles at Olympia had not fallen face downward in soft mud, but instead had been buried in gravel, its beauty would have disappeared. The texture of the surface which is the marvel of sculptors would have been obliterated by the solvent power of ground water.

The archeological history of Pompeii and Herculaneum shows the importance of a suitable cover. Pompeii was buried beneath thick beds of porous volcanic ash. Because of the porous character of the deposit, underground water carrying oxygen and carbon dioxide could readily circulate. One effect has been the rotting away and disappearance of wooden objects. Seldom is any uncharred wood preserved. Herculaneum was buried under a relatively impervi-

ous volcanic mud, which prevented the circulation of water. As a result of the absence of daily changes of temperature and of the circulation of ground water, organic objects are much better preserved.

The Necessity of Scientific Research for Stone Preservatives

Whether or not archeologists agree with the above suggestion, they will concede that Greek and Roman antiquities should be preserved if such can be accomplished without depriving the scholars of to-day of the pleasure and profit of studying them. Therefore, one of the most obvious needs of archeology is preservatives with which to treat stone objects so that they will not crumble and dissolve. Without stone preservatives the excellent and costly restorations of Mayan temples which are now being constructed in Yucatan will have a short life.

The writer feels that immediate steps should be taken to provide a fund for the encouragement of scientific research along these lines. The knowledge derived from such studies would be of value not only to the archeologist but also to architects who plan buildings which, they hope, will endure for centuries. Such investigation would probably be expensive and might require several years of experimentation, but it is imperative if existing remains are to be saved.

Summary

A few of the many striking examples of the destruction by the weather of works of antiquity have been pointed out. Two suggestions for the preservation of archeological finds are offered. The first is to re-bury excavations after they have been thoroughly studied; the second is that scientists be encouraged to search for some means by which objects exposed to the weather can be kept from disintegration.

Until some method is discovered for preventing the decay of works of antiquity, excavations should be limited. In this connection it is interesting to note that improved archeological methods are being discovered. It will be recalled that, in the older excavations of Pompeii, trenches were dug and the digging proceeded from the side of a building inward. In the new excavations the digging is from the surface downward. In this way when a cavity such as that left by the entire decay of the wood of a door is encountered, plaster is poured into the cavity and a cast of the wooden object is obtained. This is well shown in the house of Menander, where a cast of a wooden door with a broken bronze bar is propped up with a cast of a log of wood. With the methods formerly in use such discoveries were improbable. The fact that archeological methods are improving should cause archeologists to hesitate to make any but the most necessary excavations.

Some scholars will probably feel that the men of the present need have no thought for the people of a thousand years hence; that some new political disease or government may have caused the Parthenon and the Coliseum to be torn down for building stones or because of a passing fancy that a knowledge of the past should be obliterated. Perhaps some will go so far as to say that we are now enjoying the warmth of an interglacial period which will be followed by refrigeration, and that the future is too uncertain to be considered.

Assuming that conditions remain as they now are for some thousands of years, and that the human race will not deteriorate during that time, failure to protect the monuments of antiquity for future scholars will make appropriate the sarcastic remark of Job: "No doubt but ye are the people and wisdom shall die with you."

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE UNITED STATES DURING THE ICE AGE

By Professor J HARLEN BRETZ

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So you think the climate must be changing? We surely have been having unusual weather for the past few seasons. A drought without precedent, a summer hot beyond all records, winters so mild in the East and Mid-West that Florida and California lose almost all their charm. The memory of the oldest inhabitant is hard-pressed to match these recent extremes. But weather in this latitude is always surprising us; one reason why it's always a satisfactory beginning for any conversation. And what you perhaps thought was climatic change has been only weather variability. Since climate is the average of the weather over a long period of time, it is obvious that climatic change must be extremely slow. Our Weather Bureau should be allowed to collect figures on rainfall, snowfall, temperature, winds, etc., for a hundred years yet before we press them with the question "Is our climate changing?"

What about records of climatic changes before the weather man began making his records? We have them. Geologists, rather than meteorologists, have supplied us. What do you think about that "Ice Age"? Didn't it require a much colder climate than we now have in Canada and northern United States? "But," you may say, as my granddad always said to me, "that Ice Age stuff is all theory." I never could convince him; he knew no geology and he was "sot" in his ways. He knew what he wanted to believe, and what he didn't want to believe. Can I convince you in the very brief time I have?

Almost everywhere on the land there is a surface cover of soil and subsoil overlying firm bedrock. In most places this soil and subsoil is a product of the decay and disintegration of the bedrock itself. Its boulders are all of the underlying kind of rock, its texture is coarser with increasing depth and it grades imperceptibly into the undecayed bedrock. There is no sharp break between soil and subsoil above and bedrock below. But in the northern part of the United States, the soil and subsoil rest with sharp contact on undecayed bedrock. There are boulders and smaller stones in it of various kinds of rocks, unlike the bedrock itself. In many places the surface of the bedrock, when cleaned off, shows long straight, parallel scratches, running nearly north-south. Boulder surfaces also are scratched and even planed off.

These peculiar features mean that this material, overlying the bedrock of the Northern states, was transported here from some other place, that in the transportation there was a great scouring action, and that the rock fragments which grooved and scratched the underlying rock surface and themselves became grooved and scratched were rigidly held in position and rigidly held on one course. Stream-carried stones do not get scratched this way nor do they make scratches on the rocky stream bed. Waves do not move their pebbles and cobbles in such a way as to make these

markings. The only agent which shifts loose material about on the land surface to produce these markings is glacial ice. Geologists have run around enough and looked at the earth's features enough by this time to be of one opinion on this point. They have studied glaciers in our western mountains, in Alaska, in Greenland, in Antarctica and elsewhere. There is no ground for reasonable doubt. We do have a record, an indisputable one, of notable climatic change in the northern United States.

Under what conditions does glaciation occur to-day? For one thing, most of the precipitation must be in the form of snow. For another thing, the summers must be so short and so cool that not all the winter's snow is melted off. If a residuum of one foot of snow is left after each summer's melting, a century of time should see an accumulation 100 feet deep, that is, if no consolidation of the snow occurs. But perhaps you have seen an old snow drift after a few weeks of day-time melting and night-time refreezing. If so, you know that the last of this snow is a coarse-grained, porous ice, much denser than the original snow when the drift was made. To be a true glacier, this ice-from-snow needs only to be thick enough and to lie on a slope. The strength of ice is relatively slight and its own weight, when sufficiently thick, will deform it. Gravity thus causes it to flow very slowly downgrade, somewhat like a very thick mass of tar.

The scratched bedrock under the glacial deposits of the northern United States shows that the ancient ice sheet of North America moved southward, coming from Canadian territory. Many of the foreign boulders in the deposit ("niggerheads" or "hardheads," my granddad called them) are traceable back along the trail of the bedrock scratches to ledges of granite several hundred miles to the northward. The great ice sheet grew in northern Canada and spread out chiefly to the south. How far into the United States did it get?

The southern limit of this peculiar soil and subsoil of the United States (geologists call it glacial drift) makes an irregular line from New Jersey on the Atlantic coast to the state of Washington on the Pacific. All New England and New York are covered by the glacial drift, and the northern parts of New Jersey and Pennsylvania. Most of Ohio, Indiana and Illinois are covered, only the extreme southern portions escaping. At Cincinnati the ice sheet, recorded by the drift deposit, pushed across the Ohio River about 20 miles into Kentucky. But it reached still farther south in Illinois, there attaining its greatest extent. All the states of the Upper Mississippi Valley and the Great Lakes Region were covered, the ice invading northern Missouri, extreme northeastern Kansas and eastern Nebraska. From here the margin of the drift swings northwestward across the Dakotas and only the northern third of Montana was covered. Across the Rocky Mountains and the Cascade Range the margin is very irregular, as would be expected in a region of great relief. The panhandle of Idaho and the northern third of Washington were covered by Canadian ice.

Such an invasion by glacial ice hundreds of feet thick must have made great changes in river courses in the northern part of our country. Examining the evidence in the field, we have found that the upper part of the Missouri drainage area was formerly tributary to Hudson Bay and the Arctic Ocean, and became shifted over to the Mississippi system and the Gulf of Mexico. Several rivers of western Pennsylvania, now tributary to the Ohio, were formerly confluents of the St. Lawrence system. The Great Lakes, which were river valleys in preglacial time, were modified to become the greatest group of fresh-water lakes in the world.

A climate producing such a prodigious ice sheet (covering nearly half of North America) must have favored local glaciation in the western mountains south of the main sheet of ice. We find records of valley glaciers in the mountains, like those of Glacier Park to-day, in every Western state, the high mountains of Colorado, Wyoming, Oregon and California having the largest development. Shrunken remnants of some of these still exist. Even New Mexico and Arizona had local valley glaciers during the Ice Age. The southernmost record of glacial ice in the United States occurs in southern California, south of the latitude of Los Angeles, though, of course, high up in a group of mountains.

The climatic change which caused the Ice Age was an interruption. Animals and plants living before the glaciation in the northern part of what is now the United States were temperate climate forms, as the fossil record shows. The growth of the ice sheet was enormously slow; so was its advance. Perhaps a mile in twenty years was its speed limit. Generations came and went during the refrigeration, and thus even plants, unable to pick up and walk out, had the opportunity to migrate southward. As the Arctic climate gradually developed, a great wave of sub-Arctic forms slowly moved down into the Northern states and replaced the earlier temperate forms. Many of them finally reached even the Southern states. Not all survived the stress of this migration; many species became extinct. But several animal kinds living to-day in northern North America made the two-thousand mile trip southward, and as the ice finally melted away, moved back again. Walrus bones have been found in Georgia, caribou or reindeer in Pennsylvania and Ohio, moose in Kentucky and Missouri, elk in Florida and Arkansas, and muskoxen (living to-day only in northern Greenland) have been found in Kentucky, Oklahoma and Arkansas. Fossil remains of the tamarack, a typical northern tree, have been reported from Georgia. A very curious consequence of the return of these cold-temperate and subarctic forms when the ice finally melted away is known in the New England mountains. Here at high altitudes live to-day certain Arctic plants and insects, a thousand miles removed from any others of their kind. They migrated up the mountain slopes to follow their favorite climate, while most of their kind migrated northward along the level into higher and higher latitudes.

How long ago this ice sheet melted away is known to a fair degree of approximation. The Great Lakes are a result of the glaciation and so is Niagara Falls in the river through which four of these lakes discharge. Niagara Falls exists because a hard rock layer overlies one of softer rock. Greater erosion of the softer rock beneath undermines the harder layer which breaks off in large fragments now and then. A particularly large fall of rock occurred a year ago. Thus the cataract is retreating upstream and thereby leaving a longer and longer gorge below the falls. According to this interpretation, the falls have retreated about seven and a half miles from the place where they took origin when the ice first cleared the region. The average rate of retreat per year, divided into the total length of the gorge, indicates that Niagara Falls has been in existence, though shifting its location upstream, for about 25,000 years.

How long the Ice Age endured is another question. Estimates run close to a million years. What caused this great climatic change is still another question. My time is up, but I'll take a split second more to say that I don't know. I find some comfort in my ignorance, however. No one else knows.

SCIENCE—THE GUARDIAN OF THE FAMILY HEALTH

By Dr. HUNTINGTON WILLIAMS

DIRECTOR, BALTIMORE CITY HEALTH DEPARTMENT, BALTIMORE, MARYLAND

I WONDER if you realize how much you owe to science, that ever-alert guardian of your health? Science means knowledge, or the knowing about all that goes to make up the world and the universe. For many centuries man has been trying to learn how to explain the mysteries that surround him, while the latest discoveries of science are constantly making possible new mysteries or miracles. This radio broadcasting is a good example of what we take for granted to-day, but would have considered a miracle fifty years ago. Some of the earliest scientific curiosity was concerned with the stars. This led to the science of astronomy. In those early days men were also curious about their bodies, and used to wonder and wonder about what it was that made them sick or kept them well. The best they could do was to guess, and they guessed that sickness was caused by evil demons or by their human enemies, who used magic or charms against them. Of course they guessed wrong, because they had no real science to tell them the truth.

It was not until about the time that Columbus was discovering America that modern science was having its beginning with the experiments of the great Italian, Leonardo da Vinci. Fifty years later Vesalius, the anatomy professor, laid further foundations in the structure of modern scientific medicine and from that time to this experimental scientific research has been constantly at work removing preventable disease and building up methods of health protection. Many branches of science have joined hands in this great task. Medical science has held a central position and has been assisted by chemistry, engineering and psychology, to mention but a few of the chief contributing sciences. What has been the manner in which these great forces have banded together to guard the health of the human family?

A hundred and fifty years ago smallpox was nearly as common a disease as measles is to-day. George Washington was pock-marked by it, and in Europe, kings and other royal and ordinary folk died because of it. There is no more brilliant page in the history of medical science than the one which bears the story of the young country doctor, Edward Jenner, whose great discovery resulted from the chance remark of a dairy maid. She said she could not take smallpox because she had had cow pox. This led Jenner to the most exact and careful scientific experimenting, and consequently we rarely see a case of smallpox any more. Vaccination is a word known to most school children because of personal experience.

Chemistry was the chosen field of service of France's greatest hero, Louis Pasteur. His features and not those of Napoleon adorn the postage stamps of the French nation to-day. Chemistry, so closely allied to modern medicine, led Pasteur to study fermentation and thence to the germ theory of disease. On he went to discover some of these tiny germ or microbe enemies of mankind and to make possible with the great German, Robert Koch, the discovery of many more. Every time we think of hydrophobia we should think of the Pasteur treatment for its prevention. Every time we drink a glass of pasteurized milk we should thank the science of chemistry for the man who has probably been responsible for the saving of more

human lives than any other single member of our race.

Let us think for a moment of the time when a drink of water anywhere might mean death from typhoid fever. Many of those who are listening know of this peril of the recent past. Which of the sciences guards the family health from the danger of that great killer? Engineering gives us the splendid filtration systems that guard the millions in our larger cities. Chemistry has added chlorination which is able to put the finishing touch on the very few and hardy germs that survive filtration or that are in our unfiltered rural water supplies.

Psychology, too, is one of the great sciences that is lending its aid in the protection of the family health. The modern mental hygiene movement which is based on psychology dates back only as far as 1908, when Clifford Beers wrote his marvelous autobiography, "The Mind that Found Itself." Ask your family doctor how many of his patients come to him because of some human problem that has distressed their minds or consciences. You will be surprised at the number. Such mental difficulties often develop and appear in the form of body symptoms. Mental tribulations are as old as mankind itself, and a striking illustration from Bible times is the story of the devils that went into the herd of swine which then ran violently down a steep place into the sea and perished. Nowadays science has shown that mental ailments may be treated just as effectively as physical ailments are treated and there is no sense of shame attached to them as formerly. This alone is a tremendous gain. Mental hygiene is also much concerned with happy family life and with the prevention of any possible modern "devils" caused by maladjustments or misfits within the family circle.

How can a person convince himself that the fruits of science are being thoroughly utilized in the protection of his own health and that of his relations? As in other fields, he must make a careful study and learn first what he may reasonably expect from his government, especially in cities. This will include among other services a pure drinking water supply, a safe milk supply, proper sewage disposal and a health education program. Then he should become aware of certain activities that he must do something about for himself. These have to do with personal hygiene, the development of health habits in childhood and the regulation of life in accordance with scientific discoveries that are fundamental in the modern art of "keeping well." To-day education in this worth-while art comes from a multitude of sources. The family physician has usually been the chief spreader of health information. The schools are now giving it more attention than formerly. Newspapers, magazines, the radio and modern advertising, some of which we can believe, are filled with the health message. The wise person is like the one who was always very cautious about the sausages he ate and insisted on knowing who had made them and from what material. So in matters of health education or advertising, it is important to know something about the sources and motives back of the health information before relying too much on it.

What the individual must do for himself is now the most vital problem in the modern public health or "keep well" movement. The periodic health examination, performed by the family physician or at a clinic, is a good foundation stone. Prenatal care for the expectant mother is another. Taking the babies to the child specialist and later to the dentist at regular intervals is a very valuable practice. Soon after the age of six months toxoid or toxin-antitoxin should be given to every child to prevent diphtheria, one of the most dreaded dis-

eases of childhood. Smallpox vaccine, too, is best given at about this same age. In these and many other ways the modern person is brought in contact with a point of view that health and disease are not mere accidents or chance happenings, but that positive health is something that can in many ways be planned for and to some degree ensured.

What of the future? There can be no doubt that our present health conditions will some day be looked back upon as quite barbaric. Much more scientific research is needed to give us a cause, a cure and a prevention for such death-dealing maladies as cancer, influenza and certain other fatal diseases. The unsanitary conditions now existing in the crowded and poorer sections of our cities, the present neglect of rural hygiene, the pressing need for an adequate attack on the venereal diseases through education, these and a host of other problems will long remain with us. For their solution we must look to our men of science. If we, every one of us, are on the alert to apply the scientific knowledge we now have in health matters, we can do much to prevent needless misery and suffering. Remember that health knowledge is not static, it is living and growing. It is up to us to make use of it. For example, we can now eradicate diphtheria if we desire sufficiently to do so. Are we doing anything about it? Let's get busy and join science as guardians of our families' health.

OUR PATENT SYSTEM

By Dr. EDWIN J. PRINDLE

PAST PRESIDENT, NEW YORK PATENT LAW ASSOCIATION

I VENTURE to say that to many readers our patent system is not much more than a name; that you scarcely know whether it is of any importance to our economic system. To learn what it has done for us, we need only to contrast the condition of our country before the establishment of our patent system with the condition after it had been finally perfected and really gotten to working. At the time when it was established, we were a group of purely agricultural and non-manufacturing colonies. Agriculture was conducted by the use of hand-tools, which the farmer not only guided and applied to his work, but which he had to drive by the power of his own muscles. Only the surface of the earth was tilled, and that was hardly more than scratched. The crops were light, and the labor so great that a man could cultivate but a few acres. There had been practically no improvement in agricultural implements for thousands of years. The American farmer was farming almost as the Egyptians did, when the Children of Israel were there.

Then came our patent system, saying, if any person would invent or discover any new and useful art, machine, article of manufacture or composition of matter, a patent would be granted, giving him the exclusive right, for seventeen years, to make, use and sell his invention; that is, the right to exclude every one else from any making, using or selling of it. As a result of this offer the farmer was gradually supplied with machinery which he had only to control and guide, and which often saved him even the trouble of walking. So great was the transformation effected that, with some crops, such as wheat, one man could do the work formerly requiring ten. Crops became more abundant and of better quality; the area which a man could cultivate was increased manyfold. On some of the larger up-to-date farms

to-day, where machinery is used to the fullest extent, only one man is required for every 250 acres.

If, during the Great War, the American farmer had not had this machinery to use, the shortage of labor caused by raising and equipping our army and navy would have made it almost impossible to feed our own people and would have left Europe to starve. The invention of farm machinery not only benefited the farmer; but the manufacture of that machinery became a great industry giving profitable employment to very large numbers of workers.

This effect on the American farmer and workers is only one example of many produced by our patent system. For instance, American-invented machinery makes shoes as good as any but the most expensive hand-made ones, and at prices with which foreign hand labor can not compete. This, too, created an enormous industry. By means of American-invented machinery, the American motor industry has been enabled to turn out high-grade automobiles by the thousands per day, and at prices impossible for foreign manufacturers to meet. This again afforded employment to an army of workers. The patent system has transformed and enlarged almost every branch of industry and, up to the time of the depression, made it possible for our workman to be so paid that he could live on a scale far above that of other countries, and still compete with cheap labor abroad.

Although most Americans are of European stock, and, therefore, are not naturally more inventive than Europeans, yet it is a fact that more than two thirds of all the inventions of primary importance, which have been made since the establishment of our patent system, were produced by American inventors. Only a small part of the wonderful development which I have sketched would have been attained, had it not been for the inducement of our patent system. Furthermore, this system is necessary to the bringing about of the perfection and commercial development of most inventions. For the making of an invention requires not only thought, but experiment and research. The devising and testing of possible solutions of the problem in hand, to ultimately find a way by which the desired result may be attained and that is sufficiently free from objections to make the invention practical and desirable; the building of a seemingly perfected device; and testing it under commercial conditions, often require costly facilities, endless patience and a large expenditure of time and money.

The result is that capital is almost always required to perfect an invention and to get it ready for marketing. The expense of developing a single invention not infrequently runs into thousands, and sometimes, as with the steam turbine, into millions. Without the possibility of recovering this expense, and making a profit on the invention, neither individuals nor companies could afford to make and perfect inventions. For, if there were no patent law, then when the invention had been perfected and put on the market, a competitor could copy it; and, not having had any expense of developing or perfecting the invention, he could sell it at a price far below that of those who, having perfected it, are burdened with the cost of doing so.

This is so true that if the immortal Edison could not have protected his inventions with patents, he never could have raised the capital which most of his inventions required for their development, and without which they could not have been produced. His expenditures in the development of inventions throughout his career amounted to many millions. In the latter part of the development of his incandescent electric light, Edison had as many as 100 men at work

in his laboratory. Not only this, but he sent expeditions all over the world before he found a vegetable fiber which could be made to serve as the filament of his lamp. When his electric light had been reasonably perfected, he still had to invent his clever electric distributing system, by which each lamp could adequately be supplied with current, independently of every other lamp throughout a large area. He then had to improve the dynamo, so that an enormous amount of current could be generated and maintained steadily at just the right voltage; and to invent the safety fuse to protect each lamp; the meter, the plugs, sockets, etc. Altogether, Edison took out 375 patents relating to electric lighting alone.

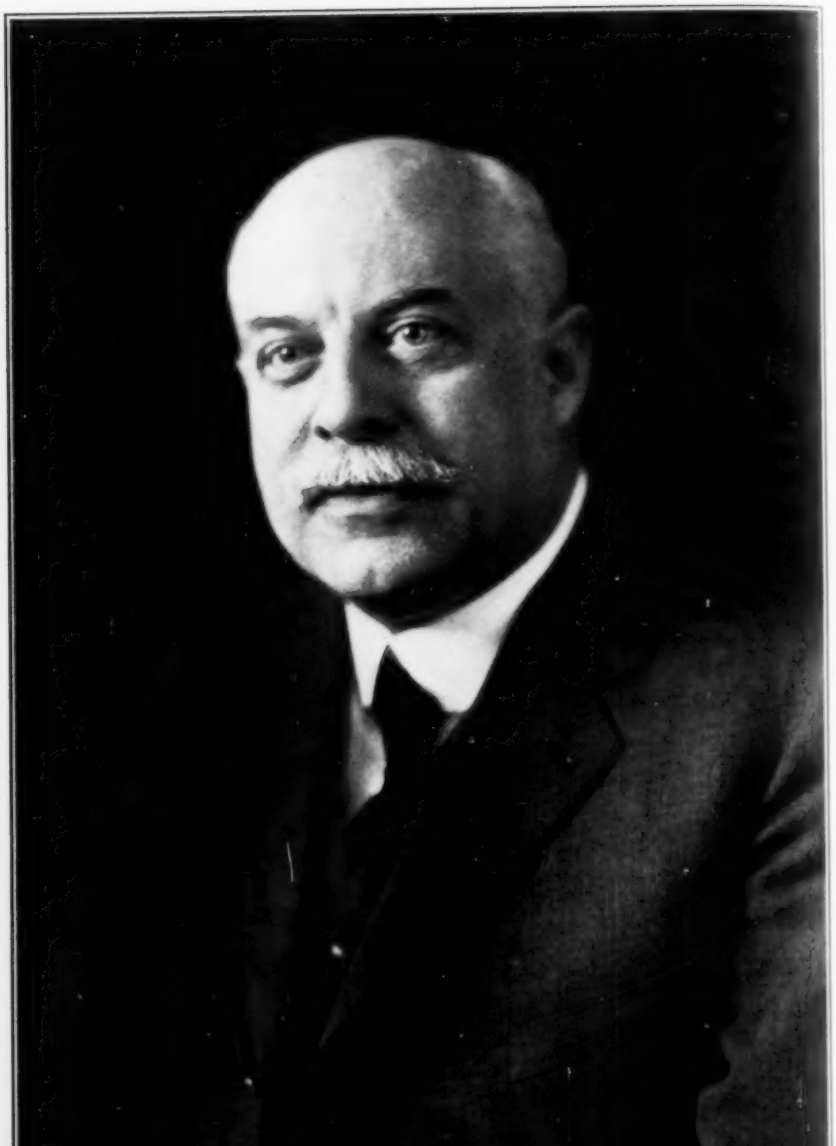
Among his multitude of other inventions are his carbon telephone transmitter—that transformed the Bell telephone from a mere laboratory curiosity into a commercially indispensable utility of the highest value; his phonograph—which is the foundation of the talking-machine and music reproducing art; and his motion picture projector—that for the first time gave the appearance of continuity and life to projected pictures, and which to-day is universally used; these inventions of great value to mankind required great sums for their development.

Without our patent system, the world would have been deprived of most of the inventions with which Mr. Edison blessed it, and which have added to the wealth, comfort, happiness, and employment of mankind beyond calculation. Mr. Edison's career also affords one of the most striking proofs that our patent system is an open door through which the man without capital, or college education, may possibly reach independence.

While labor-saving machinery may be responsible for some of the unemployment to-day, the same lure of the patent system that induced the inventing of the labor-saving machinery will surely cause the inventing of new products and the establishment of new industries that will afford employment to all our people. Who can say but even greater wonders than we have yet seen may be given to us in the future, if we keep the reward for their discovery sufficiently attractive to our inventive genius?

Because a patent for an invention is a monopoly, some think it is harmful, since most monopolies are so. But when the British Parliament, in 1623, prohibited the crown from granting monopolies of the sale of ordinary commodities, such as salt, it expressly excepted Letters Patent to the "first and true inventor" "of the sole working or making of any . . . new manufacture," because it recognized the great benefit these new inventions would bring to the realm. As a patent for an invention only gives the inventor a monopoly of that which he created, it takes nothing from the public; but at the end of seventeen years gives the invention to the public free.

Our patent system has been the primary factor in making America foremost among the nations, in agriculture, inventing and manufacturing. While there are other factors, the patent system is by far the most potent one. In its total effect it has greatly increased employment of labor and capital.



GEORGE KIMBALL BURGESS

THE PROGRESS OF SCIENCE

GEORGE KIMBALL BURGESS

SCIENCE has lost a capable executive—a devoted leader successful in both research and administration. On July 2, 1932, Dr. George Kimball Burgess was stricken with cerebral hemorrhage at his post as director of the National Bureau of Standards and died on his way to the hospital without regaining consciousness. Dr. Burgess was born on January 4, 1874, in Newton, Massachusetts, and died at the age of 58. In 1901, he married Suzanne Babut, of Paris, France, who survives him.

The extent of his responsibilities, all too many, perhaps, was a measure of his mental alertness and active interest. These continued to the end. The tact with which he dealt with situations was such as used a smile in place of an argument. He thought clearly and acted decisively in a manner to disarm criticism.

His practical turn was early reflected in his choice of a thesis subject, "The American Merchant Marine," on graduation from the Newton school system. In 1896, at the Massachusetts Institute of Technology, he conducted work on standards of pitch and collaborated in preparing Holman's "Precision of Measurement." He served successively in Harvard College Observatory, the University of Paris, the University of Michigan and the University of California.

His interest in pure science was shown by his choice of subject for his thesis—"Recherches sur la constante de gravitation," submitted to the University of Paris in 1900 for the degree of doctor of science. The University of Paris at the time awarded him the highest commendation, "Mention Très Honorable." His interest in this subject was renewed when, as director of the Bureau of Standards, he authorized a redetermination of this universal constant.

His book, "High Temperature Measurement," written jointly with Le-Chatelier in 1900, is, in revised form, still almost the only authoritative text on high temperature.

In 1903 Dr. Burgess was appointed assistant physicist in the Bureau of Standards. In 1905 he became associate physicist, and in 1913 he was appointed chief of the division of metallurgy. On April 21, 1923, the President of the United States appointed him director of the Bureau of Standards. His first annual report was a classic and has never been excelled as an administrative analysis of the work and achievements of a research organization.

As expert in metals, Dr. Burgess was deputed to go to the front to study the use of metals in warfare. He brought back a wealth of data as a foundation for research programs and the more efficient use of metals in war. As a member of the Aircraft Materials Specifications Board he rendered great service in the international standardization of materials used in aviation. His extended research program on railway materials was notably fruitful. To Dr. Burgess must be credited the introduction of pyrometry in the American steel industry.

He was perhaps the first to measure the temperatures of steel rails as they were formed in the rolls. He found finishing temperatures above certain critical points on the cooling curve of the steel, and recommended a reduction in the permissible temperature of finishing.

His ingenuity was illustrated by his micropyrometer, with which the melting points of microscopic particles of substances could be determined, thus opening up a new field in high temperature research. With this he was personally responsible for the determination of a vast quantity of valuable data widely used in the high temperature field.

His mastery of fundamental science was illustrated in his early proposal (1908) for a new type of standard of

light. This has recently (1929) been realized experimentally with great success in the laboratories of the Bureau of Standards. Radiation from a small aperture in a uniformly heated enclosure depends only on the temperature. Immersed in freezing platinum (the temperature of which is a constant of nature) a tube of thoria emits visible radiation of a quantity and quality which is invariable. Prospects are excellent that this reproducible source will be adopted as an international standard of candlepower.

Dr. Lyman J. Briggs, assistant director for research and testing (now acting director) of the Bureau of Standards, thus gives his impressions of Dr. Burgess:

"His office door was always open. Interruptions did not seem to worry him. His visitor found him dignified, but friendly, alert, attentive. He reached decisions promptly. His voice was low, his sentences crisp. His sense of humor was keen, and he responded to it with quiet body-shaking laughter. Sedentary in his habits, he had little interest in sports and games. Recreation to him meant a good book and a plentiful supply of tobacco, or a long drive in an open car with a friend. He loved the sea, and a long cruise was for him an ideal vacation.

"Dr. Burgess gave generously of his time and energy to further the interests of organizations engaged in the advancement of research and standardization.

"His memory will be cherished by the staff of the organization to which he gave the greater part of his life, and by his numerous friends in scientific and industrial circles, not alone in America but throughout the world."

THE FIRST SYRACUSE MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE ninetieth meeting of the association was held in the heart of a region famous for its universities and other scientific institutions. But Syracuse and the surrounding territory held many additional scientific interests for those who attended the meeting. Places of special interest in this connection included the Glacial Plunge Basin and Cross Channel in the vicinity of Green Lake, the Labrador Pond, the Moraine and Kettle Lakes at Tully, the Silurian and Devonian Exposures, extending from the Vernon Shale up to and including the Marcellus Shales, the Marl ponds, peat bogs, sandy fields and woodlands near Junius, the Thuja swamps around White Lake and the Salt Flats in the neighborhood of Onondaga Lake. So interesting were these places that several of the sections confined their programs to conducted field trips.

Those who had not visited Syracuse for several years were quite pleased to find that the host institution, Syracuse University, had grown from a small denominational school into a large thriving university of fourteen colleges, including Liberal Arts, Fine Arts, Law, Medicine, Engineering, Education, Forestry, Agriculture, Business Administration, Home Economics, Library Science, Speech and Dramatic Arts, Nursing, and Citizenship and Public Affairs.

The local committee, under the chairmanship of Dr. Hugh P. Baker, dean of the College of Forestry, gave much attention to the detailed work of preparing for this meeting and carrying it through to a successful conclusion. Much credit must be given to Dr. A. L. Elder, secretary of the committee, for his untiring efforts. A great deal of the program resulted from the activities of the local representatives, who, in many instances, acted for the section officials. Through the efforts of some members of the local committee excellent programs were presented by sections and societies which otherwise would not have had programs.

LYMAN HALL OF NATURAL HISTORY

The weather was ideal, except for one day which was a little too warm for some members. The delightfully cool weather both before and after this one day indicated, however, that it was really an exception.

Although only 504 registered, there were at least three or four times that many in attendance. Many who attended sessions drove their cars to the meeting, hence had no tickets to validate. A large number of these were provided with society programs and, therefore, felt no need to register with the association. Many others attended their first meeting of the association and failed to understand the desirability of registering. This was especially true in the sections devoted to chemistry, medical sciences, engineering and agriculture. For example, over 150 attended the "Land Use" symposium, but not over 10 per cent. of these registered. One hundred and seventy-five attended the sessions of the medical section on Friday, and yet only about a dozen registered. The registration, therefore, gives no good approximation to the number who attended scientific sessions.

The general programs of the association turned out to be quite interesting. All seven general addresses given in the late afternoon proved to be quite popular. Audiences at these sessions ranged from about one hundred to three hundred. As usual, the general sessions in the evening were well attended.

Dean Hugh P. Baker, chairman of

the Syracuse local committee, officially opened the meeting with a welcome from the local committee. Chancellor Charles Flint, of Syracuse University, followed with a hearty welcome on behalf of Syracuse University. Dr. John J. Abel, president of the association, responded to these words of welcome and introduced Dr. J. McKeen Cattell, who in turn introduced Dr. E. L. Thorndike, the speaker of the evening.

In delivering his address on the "Psychology of Capital," Dr. Thorndike said, "If science is allowed to do what it can do, enough material capital can probably be created from nature within a single life-time to give each of the 50 per cent., who now have least, much more than he would at the end of his life transmit to his children if he now received an equal share of all the capital owned by men." He branded as a dangerous myth the notion that manual labor is the creator of all capital and that capital as such is the oppressor of labor. Following Dr. Thorndike's address there was a general reception in the ballroom of the Hotel Syracuse.

On Tuesday evening Dr. J. O. Perrine gave a popular demonstration of the physical principles which have been used to make television possible.

On Wednesday evening Professor W. F. G. Swann gave a popular demonstration of short wave-length radiation discoveries which have led up to the discovery of cosmic rays. He showed how radium emanations from the earth ionized 1,000 molecules in each cubic centimeter of air. He demonstrated that when the radium emanations are filtered out, powerful rays called cosmic rays pass through the filters to produce a residual ionization. He proved further that these rays come vertically from above the earth.

On Thursday evening Dr. Graham Lusk gave an historical address in which he reviewed the contributions of the German scientist, Max Rubner, to the science of nutrition. On Friday evening Dr. Henry Crew outlined the advantages of making science known generally. He pointed out that many of those scientific principles exhibited as scientific curiosities at early World Fairs have contributed most to human progress.

Noteworthy general addresses were given at other sessions by Dr. Richard

SYRACUSE UNIVERSITY FROM THE AIR

THE UNIVERSITY FROM THE ROOF OF THE HOTEL SYRACUSE

Thurnwald, of the University of Berlin, Dr. Rodney H. True, of the University of Pennsylvania, Dr. W. G. Smillie, of Harvard University, Dr. Thomas Parran, Jr., health commissioner of New York State, Dr. Dixon R. Fox, of Columbia University, Dr. Frederick Slocum, Dr. E. R. Hedrick, of the University of California at Los Angeles, and Dr. W. B. Carver, of Cornell University.

Technical sessions, which were especially noteworthy for the program material presented and for bringing together important leaders in research, included those devoted to symposia on "The Biological Action of X-rays," "Land Use," "Demand and Supply," "Aerial Photographic Surveying and Mapping" and "Mental Hygiene."

Although the association held no official science exhibition, a number of very good exhibits were secured by the local committee. Especially noteworthy were the medical exhibits, the chemical ones and those of the College of Forestry.

CHARLES F. ROOS

MEDAL DAY MEETING OF THE FRANKLIN INSTITUTE

IN accordance with its long-standing custom of presenting its medals and other awards on the third Wednesday in May, the Medal Day exercises of The Franklin Institute were held this year in the hall of the institute on May 18. At this time fifteen honors were bestowed, and two papers by the recipients of its highest award—the Franklin Medal—were read. The medalists represented the United States, Great Britain, Germany and Sweden.

The Franklin Medal was founded in 1914 by Samuel Insull, of Chicago, Illinois, a long-time member and friend of The Franklin Institute. This medal is to be awarded to "those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, have done most to advance a knowledge of physical science or its application."

Two Franklin Medals are awarded each year, usually to an outstanding scientist of the United States and to some scientist from some other country. This year the first Franklin Medal was given to Dr. Ambrose Swasey, of Cleveland, Ohio, "in recognition of his development of methods and his invention of appliances for making machines, tools and instruments of the highest precision, of the design and construction of the mountings of many of the world's largest telescopes, and of his scientific vision in the establishment of the Engineering Foundation for the promotion of research and its application in the various fields of engineering."

The second Franklin Medal was

DR. PHILIPP LENARD

awarded to Dr. Philipp Lenard, of the University of Heidelberg, Germany, "in recognition of a life work devoted to fruitful research in physics, in the course of which he added greatly to scientific knowledge and especially showed that it was possible for cathode rays to exist outside the generating tube and determined the effects produced by such rays; he also discovered the electronic nature of the emission from surfaces upon which ultra-violet light falls, as well as the basic laws of photo-electricity."

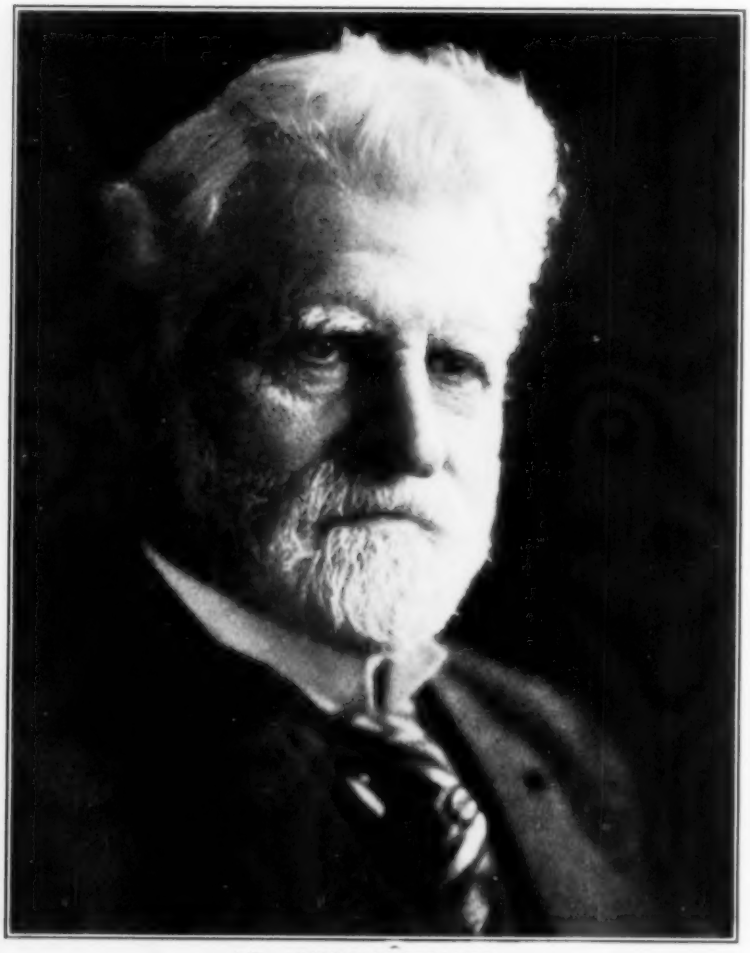
Dr. Lenard was unable to come to America to receive his medal in person because of his age. He was represented by Dr. O. C. Kiep, the German consul general in New York City.

The two addresses of the Franklin

Medalists were then read. First was one prepared by Dr. Lenard, and delivered by his friend and former associate, Dr. Charles B. Thwing. The title was "Some Scientific Views." Dr. Lenard told how, after several years of fruitless research, he had finally, forty years ago, succeeded in obtaining cathode rays in the open air, through the aluminum window of his tube. "First and foremost," he said, "I succeeded in showing that the rays are not projected atoms or molecules, for they entered into perfectly evacuated spaces in which one had not been able to produce them and took with them nothing of the nature of the matter. No trace of gas appeared in these spaces; they remained as empty as originally. Evidently the 'cathode rays' were therefore no 'radiant matter'; they must be something still more remarkable. It was then shown that they were projected negative electricity; one had here for the time obtained electricity as such, previously one knew it only when on electrified bodies or flowing in wires, but without knowing whether it was separable from these material carriers generally and was of itself a particular substance capable of being investigated. It was the negative electricity of these rays become visible. It is to-day indeed common knowledge that it consists of the small particles, the electrons, like the material of the atoms. It is these electrons, therefore, which go out from the window of the discharge tube in the form of rays, with very high velocity."

After summarizing the steps leading to the modern conception of the identity of matter and energy, Professor Lenard then presented his view of the ether. "The velocity of light is not an accidental thing and indeterminate; therefore, there must be in space something determinable relative to which it is to be considered, this something is the ether. . . . Going even further, according to the view obtained concerning matter as a special case of energy, it is to be accepted that in general every amount of energy of whatever sort has its own associated ether which always accompanies it and surrounds it as an envelope, with an attenuation extending to great, even infinite distance. This new conception appears to ascribe to the ether an especial rôle; it lets it, the ether, appear as the active agent of gravitation. In fact, it is true that, as we saw, weight, gravitation is an attribute not only of matter, but of every amount of energy, and gravitation extends, according to Newton's law, out to infinity. In fact, by means of gravitation every amount of energy is everywhere like every atom; gravitation fails at no distance; and this objective presence of all the energy of the world may lie in the presence of their ether envelopes. Ether and matter do not therefore make up the universe, but ether and energy, and these two do not stand in opposition to each other, but belong always and inseparably together; to every quantity of energy belongs its ether."

Dr. Swasey personally delivered his paper, on "Astronomers and Their Telescopes." In it he gave some reminiscences of his experiences with many great astronomers and paid particular tribute to his friend and partner, the late Mr. Worcester Reed Warner, co-founder with him of the Warner and Swasey Company, famous builders of fine machine tools. "Throughout a half century," said Dr. Swasey, "notwithstanding the fact that our work in building engines of industry was of much more importance from a financial standpoint than building engines of science, I am pleased to say that the opportunity of cooperating with the men interested in astronomical work was a rich experience which we greatly prized." Outstanding among observatories he cited the Mount Wilson Observatory of the Carnegie Institution of Washington. "Among our great men," he stated, "we have some great dream-



DR. AMBROSE SWASEY

ers and some great builders, but in Dr. George Hale we have a great dreamer and a great builder. He dreamed of an observatory on top of Mount Wilson and he built the most magnificent institution of its kind in the world. To tell you of the work of the 100-inch and of the 60-inch and the many other unique telescopes there is a story which includes all branches of astronomy. He and his distinguished staff, which includes Adams, St. John, Hubble and many others, began with the studies of our sun and now are able to tell us not only many new things about the sun and the stars, but are giving us a much clearer conception of the structure and extent of the universe. It is interesting to note that on the other side of the continent the young, enthusiastic Dr. Shapley at Harvard College Observatory has verified and extended this work of the Mount Wilson astronomers."

Both the papers of Dr. Lenard and of Dr. Swasey will be published shortly in full in the *Journal of The Franklin Institute*.

The Medal Day exercises concluded in the evening with a dinner at the Bellevue-Stratford Hotel, in honor of the medalists. Several of the honored guests, Mr. Nathan Hayward and Dr. Howard McClenahan, delivered brief addresses. About 250 visitors attended.

FOREST FIRE AS A ROCK DISINTEGRATING AGENT

THE conventional list of the forces which result in the breaking and pulverization of rocks usually includes the following (from Hilgard): Effects of heat and cold on rocks, effects of freezing water, glaciers, flowing water, wave action, winds and sand storms. Usually the effects of heat are attributed solely to solar radiation and insolation. The great heat of forest fires does not seem to have been considered as of sufficient importance to warrant inclusion in such lists.

The four photographs accompanying this note illustrate, however, the very appreciable scaling and fracturing of granitic rocks in northern Idaho as a result of the burning of dead trees which had fallen years ago. Fig. 1 shows the marked scaling where a section of a large tree had almost completely burned before it rolled down to a new position. Fig. 2 shows the remains of another burned stub that by its heat of combustion fractured the fresh rock chips nearby. Fig. 3 shows a rather large rock segment broken off by the burning of another windfallen tree. In Fig. 4

FIG. 1

FIG. 2

FIG. 3

FIG. 4

the original dead tree top lay in the crotch of the broken boulder before the fire and only the top segment of this rock showed that it was the result of a fresh fracture undoubtedly caused by the heat of the burning wood.

As the materials *in situ* prove that fire has been of universal occurrence in the past throughout all present forest types of the United States, and as the fire records of the last half century prove that forest fires are still altogether too frequent and wide-spread, it may be that the resultant rock fracturing is equally as important as that resulting from some of the other causes conventionally listed in the texts on soil formation.

H. T. GISBORNE